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Flatfoot and Its Prevention

Report on Certain Organs in a Case of Fatal Poisoning by Arseniuretted Hydrogen Gas

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THE ELECTROSTATIC METHOD OF DUST COLLECTION AS APPLIED TO THE SANITARY ANALYSIS OF AIR *

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IN the industries, the air washer and bag house for the removal of dust have in many instances been replaced by the more effective method of electrical precipitation. The present studies were undertaken with the idea of inquiring into the usefulness of electrical precipitation in the sanitary analysis of air, as compared with other methods already in use.

HISTORICAL

Many methods have been advanced for the removal of particulate matter from air and gases with a view toward studying it at closer range. The very number is indicative of the fact that most methods have serious drawbacks save under special conditions.

Dust collection for laboratory study primarily depends upon a measured quantity of air in motion. Methods used heretofore may be roughly grouped according to the principles involved in recovering dust from air.

I. *Impaction Methods.* — The dust particles in motion are forcibly directed against retaining surfaces specially prepared with sticky substances. This group includes the use of porcelain plates, paper, glass tubes, microscope slides, etc., which have been coated with glycerin (1, 3, 4, 7,), oil (5, 10), gum acacia (3), silicate of soda (3), and resin (10).

The well-known effect of dust on a photographic plate has been suggested as a convenient method to register the number of particles (4). Gravity alone (9), and centrifugalization (38) have also been used to study dust in the air.

II. *Filtration Methods.* — The principle of filtration has been resorted to in a variety of devices, the most important feature being the character of the filtering medium. For this purpose, sugar has been much used (11, 12, 13, 16, 18, 28) and to a lesser degree dependence has been placed upon extraction thimbles alone (6) or with cotton (10), cotton wool alone (1, 4, 17), resorcinol (14), fine mesh wire cloth (2), water (4, 7, 21, 38), filter paper (5, 10), collodion wool (5, 10), cheese cloth (10) and canton flannel (19).

III. *Condensation Methods* depend primarily upon condensation of water vapor around dust particles in a rarefied atmosphere. In the koniscope the resulting fog is compared with suitable standards to determine the extent of air dustiness, while with the Aitken dust counter the condensed moisture is precipitated by gravity and the minute droplets counted directly (22).

IV. *The Electrostatic Precipitation* of dust particles is based on a principle long known (23, 25, 26). The method has been recently applied commercially to the recovery of valuable dusts, but its use for the sanitary analysis of air is here reported for the first time. A discussion of the principle involved would be foreign to the purpose of this paper, but can be found in the appended bibliography (33, 34). Briefly, it depends upon the ionization of finely divided substances in an electric field, and upon the laws of electrically charged bodies.

A sample having been collected, it is essential that the characteristics of the parti-

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cles be determined. For this purpose, three methods supply facts of interest.

A. Macroscopic comparison of the turbidity of the sample with standard suspensions gives an approximate idea of the amount present.

B. Weighing methods are, however, much more accurate. The sample may be weighed after filtration or evaporation, or directly in the collector.

C. Microscopic methods. Counting the particles, either in the suspending medium, or directly on the collector, tells at once something of their size and number, as well as their character.

The disadvantages of the methods of collecting dust outlined above are many. In those depending on impaction it is difficult, if not impossible, to determine accurately the relative percentage of dust particles of various sizes retained by the collecting medium. Filtration methods have helped to overcome this and other objections, but in themselves offer new difficulties connected with weighing the dust or separating it from the filtering medium. Aitken's dust counter and similar devices have been little used because they do not permit differentiation between particles of large size which are of sanitary importance and those of smaller size and of little sanitary importance (15). The latter, however, act as nuclei for condensation and thereby are largely responsible for the large counts obtained with this instrument (13).

The ideal method of sampling dust should use a simple apparatus that is at once reliable, portable, and cheap. A pump of some sort is a necessity if large-sized samples are to be collected in a comparatively short time. Again, the ideal method would preferably use no liquid suspending medium, yet should be applicable to all kinds of dusts, soluble and insoluble, fragile and otherwise, and to fumes as well. Dust is finely divided particulate matter of varying size. It comes from all sorts of organic and inorganic material, and is of widely different specific gravities. Obviously poisonous dusts, soluble in a liquid collecting medium, will not only be lost if filtration is used in the subsequent analysis, but their importance may be missed in the interpretation of results. The ideal method should retain unchanged all the dust present in the air sample or at least the percentage actually collected should be known. Finally, it would permit obtaining of data covering weight, size, number and other physical as well as chemical characters of particles.

The activity of dust particles in an electrically charged atmosphere is a well-known phenomenon. The earliest references to this fact appeared in the literature in 1824 (23) and 1850 (24). The first practical application was patented in 1884 (36) and was intended to recover valuable dusts. Since that time, considerable work has been done by Lodge (25), Cottrell (26, 27, 28, 29), and others (31, 32), directed toward the industrial application of this principle either for the recovery of by-products or the prevention of nuisance (30).

Development of Experimental Apparatus

Since the original methods employing static electricity generated by Wimshurst and other influence machines were devised, much more reliable and more easily controlled uni-directional currents of high potential have been made possible through advances in the study of alternating current.

An apparatus for the study by electrical precipitaton of air dust must include:

1. A collecting and an ionizing electrode.
2. A high-tension transformer.
3. A rectifying device for the high potential alternating secondary current.
4. A source of alternating current to excite the transformer.
5. A pump or fan for passing the air to be studied through the electrically charged field.

It requires roughly about 30,000 volts pressure to cause a disruptive discharge across a 1-inch air gap, dependent upon the type of electrodes used and upon other factors. A secondary current of this voltage used in the collector would permit the employment of metallic tubing 2 inches or a little more in diameter, which is a convenient size to handle. Moreover, the problems attendant upon efficient insulation are easier of solution for this than for higher voltages.

With these facts in mind, the original collector consisted of a drawn brass tube of $2\frac{1}{2}$ inches outside diameter, and 18 inches long, with a wall $\frac{1}{16}$ of an inch thick. This was cut longitudinally into two parts with a slitting saw, the halves hinged and provided with catches and offset collars in such a way that the collector could be easily removed from the supporting ring, yet be

as tight as possible, and always stay in the same position relative to its axis. The supports were mounted on a verticle standard, the lower one being a ring, and the upper one being built into a small wooden header chamber with glass sides and top (Fig. 1, 1). From the back of the header chamber tin tubing, $2\frac{1}{8}$ inches (Fig. 1, 2) outside diameter, carried the air downward to a suction fan.

A 100 watt, 4 pole motor generator, running at 1800 revolutions per minute (Fig. 1, 3), was secured to excite the transformer. This runs on 110 volts direct current and gives 75 volts on the alternating side. A closed core air-cooled transformer was built to be actuated by the motor generator. This has a winding ratio of 1 to 300. While the primary was provided with variable leads so as to vary the ratio of transformation, preliminary trials showed that the 1 to 300 ratio gave the most satisfactory discharge in the collectors used (roughly 20,000 volts), and was employed, therefore, throughout the experiments. Later on, the transformer suffered a partial break-down and for that reason was immersed in oil (Fig. 1, 4).

At the time the apparatus was being developed (1915), rectifying valves were not available (30), and the choice of a rectifier lay between the disc and stick types. For several reasons based largely on the author's experience with electrotherapeutic apparatus, the stick type was chosen as offering the least difficulty in maintenance and operation (Fig. 1, 5).

It was found essential to include variable resistance in the low-tension side of the alternating current to prevent disruptive discharges, which were harmful to the entire system and which defeated the electrical purpose of the apparatus (Fig. 1, 6). Of the rectified, pulsating, uni-directional current led to the collector, the positive was led to the metal support of the collector shell and the whole grounded (Fig. 1, 7), while the negative, shown to be the most efficient for this purpose (33, 35), was led to the central electrode in the axis of the collector (Fig. 1, 8). All wires used for connections, particularly on the high-tension side, were insulated, since even a continuous bare wire will evidence brush discharges from angles or irregularities of surface.

The collector and ionizing electrode were the subjects of many preliminary tests. The glass top of the header chamber was drilled through, and acted as an insulated support for the ionizing electrode. The exhaust fan delivers by anemometer test 1624.2 linear feet per minute, or 1513.2 cubic feet of air per hour — 25.22 cubic feet per minute. The first trials with a solid duct from inlet to outlet, therefore, implied that dust particles would have a linear velocity of something less than 27 feet per second, and would be exposed in a corona discharge 18 inches long for about $\frac{1}{18}$ second. While ionization is practically instantaneous, this seemed at first glance to be too great a velocity. That this was so was shown by deposition of dust in the fan case and by the exit of portions of experimental charges. In order to correct this difficulty, a Bunsen valve with two openings about $2\frac{1}{2}$ by $\frac{5}{8}$ inches, provided with a sliding collar for closure, was installed (Fig. 1, 9) at a point 10 inches from the header chamber. With the resulting reduced linear velocity, most of the precipitating occurred in roughly the lower third of the collector. Various types of ionizing electrodes were tried. Ionizers were made of plain, heavy and light wire of different materials, heavy wire roughed by various means, and twisted wire composed of two strands. The twisted wire electrodes were found to produce the most constant and intense corona effect with the least brush discharge.

While the upper support of the ionizing electrode was a simple matter because of the glass wall there available, the lower support, because of the strain incident to tightening the wire, presented some difficulties. In a preliminary tube collector a piece of glass rod was fitted into a bayonet lock, cut in the bottom of the collector. When the divided tube was devised, a different kind of support was essential. A triangular-shaped piece of window glass provided with a wire support caused ionization of experimental charges of particulate material before the air current had a chance to pull them through. The ionized clots were thrown back on the watch glass used for applying them; moreover, considerable of the material tended to stick to the vane and the latter too introduced a factor of error into the entry of air, through eddy currents which were not desirable. An inverted V-shaped glass vane was so constructed as to rest on the edge of the lower ring supporting the collector. The ionizer

electrode, by being shortened inside the collector, influenced dust particles so that they were precipitated on the collector walls and not on the lower supporting ring. Again, the divided collector could be removed without disturbing the ionizer.

To detect particles thrown out of the collector, an old photographic negative, glass side up, was found useful as a background on which dust particles could be seen, recovered, and re-applied to the collector in a manner presently to be explained.

Measurement of Air Passing Through Collector

While a Pitot tube would have been desirable for this purpose, none small enough was available and reliance had to be placed on a standardized anemometer.

With the hinged collector in place, the anemometer was placed in as many different positions as possible in the rather limited space in the header, and with a stop watch and string control on the anemometer starting lever, ten series of runs were made with the Bunsen valve open. The fan motor was run continuously throughout these tests, and variations in line voltage were noticeable both in a voltmeter across the mains and in the variable results obtained. The variations were no doubt also due to the different positions across the cross section of the collector in which the anemometer was placed. Since the internal diameter of the hinged collector was $2\frac{3}{8}$ inches, there entered at the linear velocity of 309.85 feet per minute, 9.53 cubic feet of air through the bottom of the header, the collector being in place.

Preliminary Efficiency Tests

That some check on the efficiency of the machine might be made, a series of determinations was made on weighed portions of room dust recovered from the tops of bookcases, of which measured amounts were aspirated into the machine, regathered and reweighed. Various methods of applying the dust charges were employed. These included using the end of a knife, brushing off a piece of glazed paper, using compressed air in a device like a boiler injector, provided with a small funnel for the dust charge, rapping metal and glass plates with an electric bell, etc. The most satisfactory was found to be the following. A pair of accurately matched watch glasses was placed on the chemical balance. On one the dust or other particulate matter was weighed out to one-tenth of a milligram. The other was used as a cover in carrying the charge to the collector. The loaded crystal was then sharply rapped by hand against the bottom of the collector. This tended to reduce the amount of air passing through the instrument, which factor did not interfere with the purpose of this series of determinations but even assisted in blowing off the dust charge as the particles were dislodged by rapping. Residue on the crystal was brushed off by a camel's hair brush in such a way that the particles were swept off into the mouth of the collector by the bristles being held in a position nearly parallel to the surface of the crystal. Any dust thrown out of the collector by ionization in spite of the air current was added to and swept off the crystal from the photographic negative.

The dust was recovered by carefully brushing out the collector on the watch crystal used in applying the charge, employing the same brush used for cleaning off the watch glass. By this technic, in a series of tests using 50 mg., 100 mg., and 200 mg. charges, roughly about 80 per cent. was recovered.

In part, losses occurred: (1) through brushing, causing some of the finer particles to fly into the air, both in applying and recollecting; (2) through part of the charge sticking to the collector supporting ring; (3) to a portion of the charge being retained on the ionizing electrode and its lower support; (4) to particles being retained on the brush; and (5) to heavy gritty particles, siliceous in character, which rapidly fell off the collector walls after the current was turned off.

Attempts to correct these errors were made as follows: (1) All air currents in the room were eliminated so far as possible by closing doors and windows, by breathing behind a mask, and by using utmost care in brushing. (2) The collector supporting ring was brushed off so far as practicable in recollecting, as was (3) that portion retained on the ionizing electrode and its glass vane support. This latter was replaced by a V-shaped support of 2-mm. glass rod, following tests using finely divided paper particles. (4) The small amount retained by the brush (which was a 1-inch, flat camel's hair) was recovered by sharply rapping the latter vertically on the photographic negative. (5) The crude dust

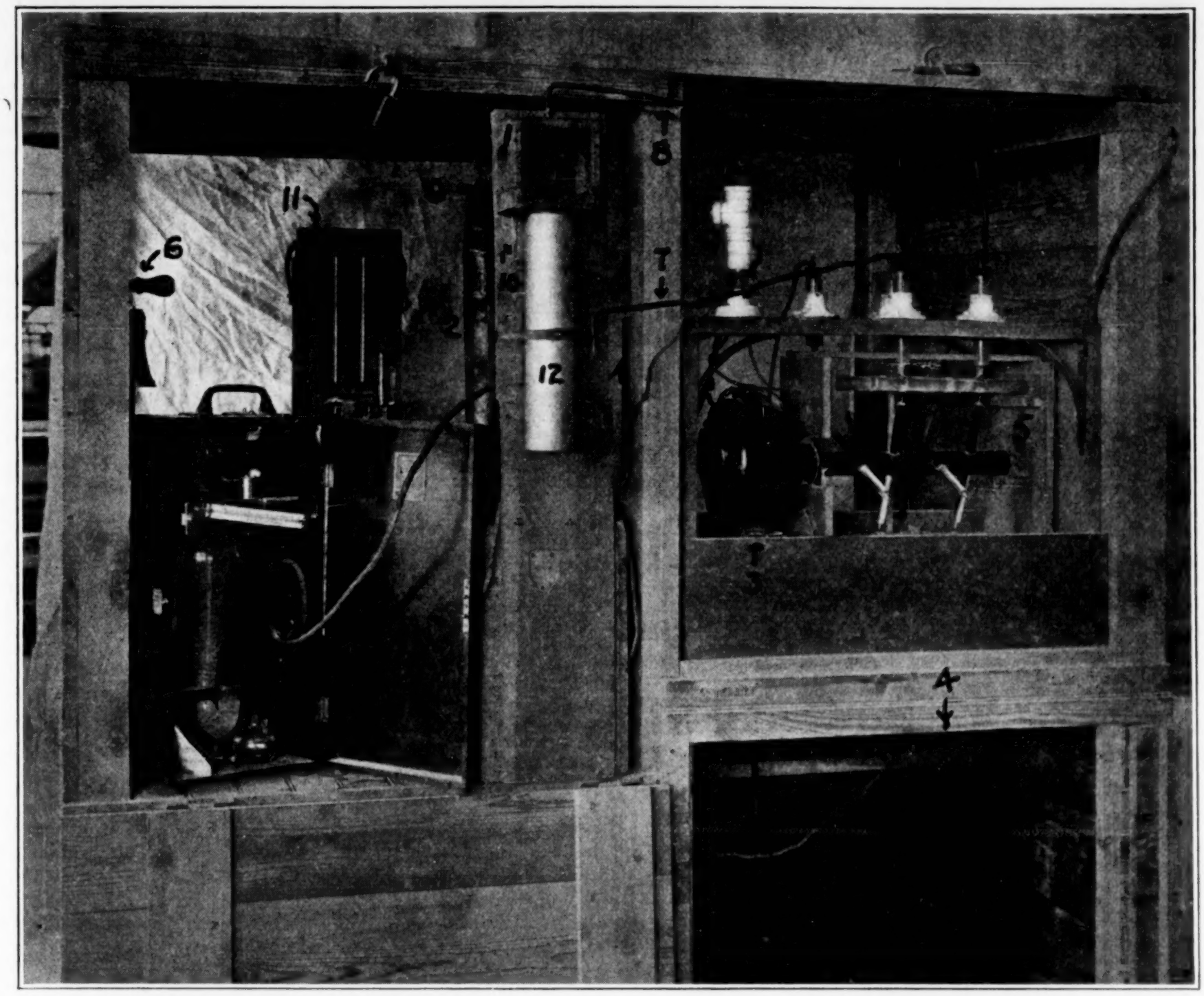

FIG. 1. — 1. Header chamber. 2. Conveyor duct. 3. Motor generator. 4. Transformer. 5. Rectifier. 6. Low-tension variable resistance. 7. Positive high-tension lead, grounded. 8. Negative high-tension lead, to ionizing electrode. 9. Bunsen valve in conveyor duct. 10. Sliding valve, to restrict cross section of conveyor duct. 11. Portable psychrometer. 12. Collecting electrode.

was sifted through 100-mesh wire cloth and only the portion passing through used. An electric bell tapper applied to the wire cloth expedited this process. In addition, a number 7 rubber stopper with a stirring rod handle was used for a policeman. With these changes in technic slightly higher returns were obtained. (Table I.)

It was suggested that weighing the collector with its dust deposit might offer facts of interest. The brass collector, however, weighed 1300 grams, and since the dust charges were small and no scales available, weighing over a kilogram with a sensibility of at least 1 mg., this procedure had, for the time being, to be abandoned.

It was noticed in making maintenance tests, when the apparatus was first constructed, that evidence of copper salts appeared in the upper stretches of the collector. Beads of moisture, moreover, in the same region gave a strong acid reaction to litmus. This was assumed to be due to nitric acid. Furthermore, it was noticed that the effect of ozone in a confined room after several hours run was markedly irritating. There arose, therefore, the possibility of chemical changes occurring in the dust. In addition, the question of moisture being responsible for a possible source of error presented itself.

Pyrogallic acid was chosen to study these points because of its availability, color, small size of particles, and chemical instability. Psychrometric readings were made on the air of the laboratory to determine the amount of water vapor passing through the collector. Later, tests were made to determine the hygroscopicity of sifted dust similar to that used above. Weighed quantities were put in a dessicator for periods covering several days. In 50-mg. charges, there was no appreciable loss of weight, but with larger quantities (over 1 gm.) losses of nearly 1 per cent. were encountered.

The gallol charges showed definitely the

distribution of particles under ionization. At the bottom of the collector a dead area appeared, somewhat shorter than the effective length of the ionizer support, which was $2\frac{3}{4}$ inches long. Above, a clear white zone about $1\frac{1}{2}$ inches wide was followed by a wider one about $4\frac{1}{2}$ inches long, wherein the gallol had a slight brown discoloration and above which only a very few scattered particles were to be seen. Whatever the nature of this change might be, it apparently depended in part, at least, on relative humidity. For example, the discoloration was more marked with an absolute humidity of 6 grains than with 2.4 grains per cubic foot of laboratory air, varying from a faint straw color to a decided brown in the former instance. With gallol this color can be detected after short exposures (about two minutes) and becomes somewhat intensified after prolonged exposure (ninety minutes). Disruptive discharges, when they occurred, manifested themselves afterward in the form of punctate areas in the deposit where the crystals were destroyed.

Because evidence of corrosion such as previously mentioned still appeared in a region apparently above the effective zone of precipitation, the ionizer support was lengthened to $5\frac{1}{2}$ inches. After this change, the corona discharge not only was more intense, but corrosion disappeared. A series of gallol charges was applied to the collector, and on recovery averaged 92.7 per cent. returned.

Humidity is an essential for electrostatic precipitation (32). Whether or not humidity in connection with nitrous oxid or by itself has any effect on the precipitated material, is, with the possible exception of the suggestive observation made in connection with gallol, unknown. Talc was next used, as a more or less inert material, to determine whether losses in recovered weight were due to the character of the material or to the technic of recovery. It was at once evident that considerable of this material remained on all of the surfaces affected as well as on the camel's hair brush. A sliding valve in the back of the header chamber (Fig. 1, 10) being opened and closed only while the ionizing current was turned on, the losses could not be explained even in part by passage of particles through to the fan. The material on the blades and hub was compared under the microscope, however, with talc particles by direct and indirect lighting, and all examined gave an entirely different appearance. Moreover, a 500-mg. charge of calcium carbonate, passed through a 100-mesh sieve, and applied rapidly with the idea of forcing some to pass un-ionized, if possible, yielded 472 mg. on recovery. The fan was carefully cleaned and the detritus acidulated with hydrochloric acid and given the flame test for calcium, with negative results. Previous experience had shown that most of the material passing through the conveyor system tended to lodge on the fan.

Attempts to weigh the small portion of experimental charges gathered by the brush seemed to be difficult because of the hygroscopicity of hair. A special brush made of long bristles with split and flesh ends removed, bent in the middle and wired into an aluminum holder, offered the same difficulty. A camel's hair brush, for instance, dried over sulphuric acid for 48 hours weighed 12.147 gm. Left overnight on the scale pan with the door partly open, its weight had increased by 93 mg. It seemed reasonable, however, to assume that if the brush under room conditions was weighed before and after use that the difference would represent fairly accurately the material gathered by it. Further tests using talc and magnesium oxid were made and brush losses determined, with unsatisfactory results. (Table I.)

Loss in Weight

As far as these tests demonstrated them, the losses of weight in artificially applied dust charges may be summed up as:

1. That attendant upon applying the charge.
2. That pulled through the ionizing zone.
3. That due to possible electro-chemical changes.
4. That due to electrical attraction of covering watch crystal for charge while being carried from scales to collector.
5. The portion lost in recovery because of:
   (a) Not brushing or scraping all out of collector.
   (b) Residue on ionizer (37).
   (c) Brush and policeman loss.
   (d) Loss in applying recovered charge to scale pan for reweighing.

1. Upon the choice of brushing off total charge or of jarring off all that can be so dislodged and following this by sweeping, comment has already been made, based on the writer's experience, in favor of the latter.

2. With air currents of low velocity such

as finally used, together with care in allowing air to pass through only when the corona discharge is operating, there is no tangible evidence that loss of weight occurs from dust charges pulled through the ionizing zone. During disruptive discharges, however, which are of the flaming arc type, the corona disappears. There is, therefore, a chance for (a) the air current to sweep off some of the material, and (b) for the dever, to eliminate them, at least so far as dust on the collector walls is concerned.

4. Loss due to electrical attraction of covering watch crystal for charge was noted in but few instances. If the crystals are placed together before weighing sufficiently long for both to assume the same polarity, it will not happen.

5. The loss encountered in recovering experimental charges is apparently the

TABLE I. — PRELIMINARY TESTS

Material	Time of Application m. : s.	Charge mg.	Return mg.	Brush Weight Increase	Total mg.	Per Cent. Returned	Per Cent. Lost	Group Average %	Barometer inches	Dry Bulb F.	Wet Bulb F.	Relative Humidity %	Absolute Humidity gr. cu. ft.
Dust	....	100	70	....	....	70	30						
Dust	....	100	75	....	....	75	25						
Dust	....	200	165	....	....	82.5	17.5						
Dust	....	200	155	....	....	77.5	23.5						
Dust	....	200	177	....	....	88.5	12.5						
Dust	....	200	178	....	....	89	11	80.4					
Paper	....	200	200	....	....	100	....						
Paper	....	200	200	....	....	100	....	100					
Gallol	....	200	197	....	....	98.5	1.5						
Gallol	....	200	186	....	....	93	7	....	30.42	63.5	52.5	47	3.08
Gallol	....	200	190	....	....	95	5	....	30.42	65	55.5	54	3.66
Gallol	3:10	50	45	....	....	90	10	....	30.25	70	54	33	2.63
Gallol	3	50	45	....	....	90	10	....	30.25	70	54	33	2.63
Gallol	1:7	50	45	....	....	90	10	....	30.25	70	54	33	2.63
Gallol	2:20	50	45	....	....	90	10	....	30.25	70	54	33	2.63
Gallol	2:18	100	91	....	....	91	9	....	30.12	68	52	31	2.31
Gallol	2:34	100	97	....	....	97	3	....	30.12	68	52	31	2.31
Gallol	1:59	100	93	....	....	93	7	....	30.12	68	52	31	2.31
Gallol	2:22	100	94	....	....	94	6	....	30.12	68	52	31	2.31
Gallol	2:33	100	94	....	....	94	6	....	29.7	73	64.5	63	5.52
Gallol	2:10	100	91	....	....	91	9	9.27	29.4	73	64.5	63	5.52
Talc	1:50	50	35	....	....	70	30	....	30.2	67.5	54.5	41	2.96
Talc	1:47	50	32	....	....	64	36	....	30.2	67.5	54.5	41	2.96
Talc	1	50	35	....	....	70	30	....	30.3	67.5	54.5	41	2.96
Talc	2:10	50	39	....	....	78	22	....	30	70.5	54	31	2.47
Talc	1:30	50	42	....	....	84	16	....	30	70.5	54	31	2.47
Talc	2:20	50	40	....	....	80	20	....	30.12	69	53	32	2.47
Talc	2:3	50	39	....	....	78	22	74.8	30.12	69	53	32	2.47
Talc	2:30	100	85	13	98	98	2	....	30.12	71.5	53.5	27	2.24
Talc	2:27	100	90	12	102	102	+2	....	30.12	71.5	53.5	27	2.34
Talc	2:12	100	89	15	104	104	+4	....	29.88	68.5	55.5	40	2.99
Talc	2:20	100	89	19	108	108	+8	88	29.88	68.5	55.5	40	2.99
MgO	2:17	50	44	10	54	108	+8	....	30.37	67.5	52	32	1.95
MgO	3:10	100	93	8	101	101	+1	....	30.24	64.5	49	33	2.23
MgO	2:17	100	95	7	102	102	+2	....	30.24	64.5	49	33	2.23
MgO	2:38	100	95	4	99	88	1	....	30.24	64.5	49	33	2.23
MgO	1:55	100	93	2	95	95	5	92.8	30.24	64.5	49	33	2.23
CaCO	....	500	472	4	476	95.2	4.8	95.2					

Total average return, all tests, 89.2% Total average return, excluding paper tests, 87.7%

struction of a small portion. It is essential for the most favorable effect that just enough resistance be placed in the alternating primary to bring down the discharge below this point. Due to variations in secondary potential of various causes, disruptive effects or static discharges may, however, occasionally occur.

3. As applied to ordinary dusts, electrochemical changes are unknown. Design of the collector to include only the most effective precipitating zone will tend, howlargest. It certainly is the most obvious. As will be shown later, 5a, 5c, and 5d are obviated by weighing the collector with its dust charge *in situ*. Dust remaining on the ionizer may for ordinary purposes be ignored since it is impracticable to try to recover it.

A further possible source of change in weight, but one which was not inquired into, is the effect of different atmospheric conditions. In the practical use of the machine, humidity was determined by means

of a portable psychrometer (Fig. 1, 11), and other data were obtained to facilitate further work on the subject. The time during which the charges were applied is also given, wherever taken.

This series of preliminary tests was made with the idea of studying the effect of ionization and of trying to improve the percentage recovered. Various minor changes in design and operation of the collector and of technic were adopted as they seemed best.

TABLE II. — SECOND SERIES

Material	Time of Application min.: sec.	Charge mg.	Return mg.	Return %	Loss %	Average %	Barometer inches	Dry Bulb F.	Wet Bulb F.	Relative Humidity %	Absolute Humidity gr. cu. ft.
Talc.....	1:32	50	37	74	26	....	30.32	65.5	51	33	2.23
Talc.....	2:20	50	40	80	20	....	29.71	64	53	47	3.01
Talc.....	1:27	50	32	64	36	....	29.94	63.5	50	36	2.38
Talc.....	1:32	50	38	76	24	....	29.94	63.5	50	36	2.38
Talc.....	1:41	50	39	78	22	....	29.94	63.5	50	36	2.38
Talc.....	2:27	50	42	84	16	....	29.94	64	50	34	2.12
Talc.....	2:11	50	43	86	14	....	29.94	64	51	38	2.38
Talc.....	1:55	50	44	88	12	....	29.94	64	51	38	2.38
Talc.....	1:32	50	43	86	14	79.5	29.94	64	51	38	2.38
Talc.....	1:28	100	91	91	9	....	29.94	64	51	38	2.38
Talc.....	1:30	100	91	91	9	....	29.94	64	51	38	2.38
Talc.....	1:32	100	90	90	10	....	29.94	64	51	38	2.38
Talc.....	56	100	90	90	10	....	29.94	64	51	38	2.38
Talc.....	1:37	100	91	91	9	90.6	29.94	64	51	38	2.38
MgO.....	1: 2	50	48	96	4	....	30.01	64	49.5	36	2.38
MgO.....	1: 3	50	49	98	2	....	30.01	64	49.5	36	2.38
MgO.....	1:15	50	48	96	4	....	30.01	64	49.5	36	2.38
MgO.....	1: 2	50	48	96	4	....	30.01	64	49.5	36	2.38
MgO.....	1: 2	50	47	94	6	96	30.01	64	49.5	36	2.38
MgO.....	1:11	100	96	96	4	....	30.15	66	51	32	2.24
MgO.....	1:14	100	96	96	4	....	30.15	66	51	32	2.24
MgO.....	1:25	100	97	97	3	....	30.15	66	51	32	2.24
MgO.....	1:55	100	99	99	1	....	30.15	66	51	32	2.24
MgO.....	1:26	100	98	98	2	97.2	30.15	66	51	32	2.24
Dust.....	1: 6	50	44	88	12	....	30.15	66	51	32	2.24
Dust.....	1:22	50	43	86	14	....	30.15	66	51	32	2.24
Dust.....	1:15	50	45	90	10	....	30.1	68	52	31	2.38
Dust.....	1:11	50	42	84	16	....	30.1	68	52	31	2.38
Dust.....	1:50	50	43	86	14	....	30.1	68	52	31	2.38
Dust.....	2: 2	50	44	88	12	....	30.1	68	52	31	2.38
Dust.....	1:23	50	44	88	12	....	30.1	68	52	31	2.38
Dust.....	1:17	50	45	90	10	....	30.1	68	52	31	2.38
Dust.....	1:40	50	44	88	12	....	30.1	68	52	31	2.38
Dust.....	1:35	50	43	86	14	87.4	30.1	68	52	31	2.38
Dust.....	1:23	100	91	91	9	....	30.1	68	52	31	2.38
Dust.....	1:28	100	89	89	11	....	30.1	68	52	31	2.38
Dust.....	1:18	100	90	90	10	....	30.1	68	52	31	2.38
Dust.....	1:22	100	89	89	11	....	30.1	68	52	31	2.38
Dust.....	1:17	100	88	88	12	89.4	30.1	68	52	31	2.38

Total average return, 90.0%

Second Series

Since the use of brushes in re-collecting seemed to introduce errors which could not be corrected, another series of tests using the same substances in charges of various sizes was made, discarding the brush and using the policeman alone. The collector was cleaned with brass polish to eliminate so far as possible any roughness due to oxidation. These tests are summarized in Table II. The average for these tests showed that 90.01 per cent. was returned.

With the idea of still further lessening chances for error by weighing the collector with its charge *in situ*, a piece of aluminum tubing of $2\frac{1}{2}$ inches outside diameter and with 18-gauge walls was procured. Since the effective zone of ionization would for the most part be covered by a length of 12 inches, this was adopted (Fig. 1, 12), necessitating structural changes in the collector supports. Instead of a bottom supporting ring, itself a cause of trouble, tension on the ionizing electrode was used to hold the tube in place, assisted by a grooved wooden block against the vertical support. The glass stirrup for holding the lower end of the ionizer was replaced by a piece of soft twisted seine twine, armed on the ends

with two small wire hooks to engage the lower edge of the collector. An S-hook in glass rod, about ½ inch long, connecting the lower end of the ionizer with its twine support, was found to prevent rotting of the twine and leakage of current.

No scales being available capable of handling an object so large, the collector weight of the aluminum collectors used was approximately 118 gm.

With the new collector sixty-three anemometer tests were made, covering periods ranging from ten minutes to nearly two hours, giving an average linear velocity of 311.4 feet per minute with the Bunsen and sliding valves open. The shell walls were

TABLE III. — THIRD SERIES: 50 MG. CHARGES: DUST

Time of Application min.: sec.	Dry Bulb F.	Wet Bulb F.	Barometer m.m.	Relative Humidity %	Absolute Humidity gr. cu. ft.	Return mg.	Return %	Loss %
2: 9	72.5	53	771.8	24	2.04	48	96	4
2:32	72.5	53	771.8	24	2.04	46.7	93.4	6.6
1:58	72.5	53	771.8	24	2.04	47	94	6
1:45	72.5	53	771.8	24	2.04	47.2	94.4	5.6
2:32	68.5	52	770.9	30	2.31	46.4	92.8	7.2
1:24	68.5	52	770.9	30	2.31	46.6	93.2	6.8
1:28	68.5	52	770.9	30	2.31	47.5	95	5
1:12	68.5	52	770.9	30	2.31	48.2	96.4	3.6
1:36	68.5	55	767.4	41	3.16	47.5	95	5
1: 2	68.5	55	767.4	41	3.16	47.5	95	5
52	73	54	761	25	2.19	49	98	2
1:42	72.5	52	764.6	19	1.66	47	94	6
50	72.5	52	764.6	19	1.66	47	94	6
1:17	72.5	52	764.6	19	1.66	48.3	96.3	3.4
58	70.5	56	757.5	43	3.42	49.2	98.4	1.6
1:22	70.5	56	757.5	43	3.42	48.5	97	3
1: 5	70.5	56	757.5	43	3.42	49	98	2
1: 4	70.5	56	757.5	43	3.42	47.5	95	5
1:13	70.5	56	757.5	43	3.42	49.2	98.4	1.6
42	75.5	54	768.7	21	2.02	49	98	2
1:24	75.5	54	768.7	21	2.02	48.2	96.4	3.6
57	75.5	54	768.7	21	2.02	49.2	98.4	1.6
1:20	75.5	54	768.7	21	2.02	48.8	97.6	2.4
1:11	70	55	768.3	36	2.68	49	98	2
1:12	70	55	768.3	36	2.68	48.7	97.4	2.6
1:21	70	55	768.3	36	2.68	48.2	96.4	3.6
1: 3	72.5	56.5	766.6	39	3.43	48.7	97.4	2.6
58	72.5	56.5	766.6	39	3.43	48	96	4
42	72.5	56.5	766.6	39	3.43	48.4	96.8	3.2
1: 1	72.5	56.5	766.6	39	3.43	48.2	96.4	3.6

Average return, 48.05 mg., 96.1%

was weighed by hanging it on a piece of hard-drawn brass wire, which passed through the bottom of the scale case, and through a hole in the scale shelf, entirely replacing the scale pan. While pendant, it was protected from drafts by a box with glass sides. The original aluminum shell was suspended by a yoke fitting in two small holes drilled through the collector walls along the upper edge. In the later shells, a sliding noose of brass wire was employed. While in the former method air friction was reduced to a minimum, occasionally particles became dislodged and fell into the watch crystal placed below. By the latter arrangement the collector was hung diagonally, but with the collected dust zone uppermost: particles on being dislodged landed on the lower wall of the collector and were thus retained. The

0.03631 inch thick. The total air per minute passing through at the average rate would be:

$$\frac{(2.5-0.07262)^2 \times 0.7854 \times 311.4}{144} = 10.005 \text{ cubic}$$

feet or 600.03 cubic feet per hour.

A series of ten tests using 100-mg. dust charges, in which the increase in weight of the collector was noted, together with that of one of the watch crystals placed underneath to catch dislodged particles, averaged 98.2 per cent., indicating that this technic offered more satisfactory results than the former in which the dust was removed for reweighing.

At this point, a Wallace Tiernan sugar filter (13) and a Palmer water spray apparatus (38) were obtained in order to com-

pare results with the high-tension apparatus. Because of the difficulty in obtaining sugar fairly free of dust particles, and owing to the fact that the relative efficiency of the two had already been determined (38), the Palmer method alone was used to compare with the method of electrical precipitation. In using the former in the laboratory, a 4 cubic feet per minute rate seemed to be the most satisfactory and an effort was made to reduce the 10 cubic feet per minute rate of the high-tension machine to one more nearly equal that of the Palmer. Accordingly, the sliding valve was provided with a stop permitting only partial opening. With this arrangement, twenty-five anemometer tests, covering 3107 minutes, gave an average of 141.64 linear feet per minute with the collector in place, equivalent to 4.55 cubic feet per minute or 273 cubic feet per hour.

Third Series

At this rate, a new series of 50-mg. charges of dust which had been passed through a 100-mesh sieve was applied to the collector (Table III). The average return for the series was 96.113 per cent. The tube was cleaned with hot running water, and a test tube brush kept for this purpose. When finally rinsed inside with dust-free distilled water used for counting, boiling water was run over the outside and shaken off, the heat of the walls then drying the interior in a short time. If hung on the wire noose while still hot, the levitating effect of warm air caused by the heated collector was particularly noticeable. Differences in temperature of the metal, that of the rooms, and relative humidity were also found responsible under field conditions for a slow change in weight, as when taking the

TABLE IV. — ATMOSPHERIC CONDITIONS ENCOUNTERED IN FOURTH SERIES

No. of Test	T	T–T′	Relative Humidity %	Absolute Humidity gr. per cu. ft.	Barometer inches	No. of Test	T	T–T′	Relative Humidity %	Absolute Humidity gr. per cu. ft.	Barometer inches
3	72.5	16	35	2.97	....	39	74	9	61	5.53	29.93
4	74	18.5	28	2.08	....	40	80.5	14.5	45	4.92	29.94
5	75.5	11	54	5.05	....	41	67	14	37	2.67	30.58
6	71	16	33	2.71	....	42	70.5	13.5	42	3.35	30.28
7	71	16	33	2.71	....	43	72	12	49	4.16	30.14
8	74	18	29	2.17	....	44	72	14	42	3.57	30.05
9	74	18	29	2.17	....	45	74	15.5	38	3.44	30.08
10	69.5	14	40	3.09	....	46	68	12	46	3.44	30.36
11	74	14	43	3.89	....	47	69.5	13	43	4.09	30.5
12	67	17	26	1.95	....	48	66	9.5	55	3.85	29.91
13	68	17	27	2.76	....	49	73.5	12	50	4.39	30.09
14	68	16.5	29	2.17	....	50	81	21	27	3.04	30.02
15	70.5	17	29	2.38	....	51	83	23.5	24	2.87	29.98
16	75	16	37	3.46	....	52	74	14	43	3.89	30.01
17	72	14	42	3.57	....	53	69.5	9	59	4.55	30
18	76	13	48	4.63	....	54	71	9	60	4.94	30
19	77	19	29	2.88	30.18	55	73	10.5	55	4.83	29.92
20	70	15.5	34	2.71	30.42	56	79	11	57	6.04	29.92
21	71.5	15	37	3.04	30.31	57	78	14	46	4.72	30.04
22	78	12	53	5.44	29.91	58	80	14	47	5.13	29.89
23	74.5	13.5	45	4.07	29.93	59	83	27.5	12	1.43	29.8
24	70.5	15.5	34	2.71	29.95	60	76	13	48	4.63	29.96
25	75	19	27	2.52	30.12	61	75	12	51	4.77	30.18
26	69.5	14.5	37	3.63	30.36	62	74	15	39	3.52	30.17
27	70.5	15	36	2.87	30.31	63	87	18	39	5.27	29.9
28	72	13	45	3.82	29.85	64	91.5	22	31	4.72	29.84
29	70.5	14.5	38	3.03	29.96	65	88	15	48	6.69	30.18
30	71	16	33	2.71	30.16	66	99.5	21.5	38	7.3	30.15
31	73	16	35	3.07	30.14	67	89	14	51	7.32	30.28
32	74	19	26	2.35	30.24	68	98	19	43	8.02	30.25
33	72.5	14	42	3.57	29.74	69	89.5	11.5	59	8.47	30.23
34	64	11	47	3.08	29.9	70	97	20	39	7.07	30.2
35	64.5	11.5	45	2.95	30.09	71	81	10	61	6.87	30.18
36	61	10	49	2.91	30.12	72	64	7	65	4.26	30.53
37	61	4	78	4.63	29.95	73	66	6	71	4.97	30.45
38	65.5	11.5	46	3.11	30.13						

Time of collecting, min.,	60	Exceptions: No. 14, 40	No. 55, 42	
Sample, cu. ft., high tension,	273	182	191.1	
Sample, cu. ft., Palmer,	240	160	168	

collector from cool dry surroundings to a warmer, more humid room, where determinations were made. In the laboratory, therefore, the collector hung about twenty minutes before weights were taken. In the practical tests of the apparatus, the rubber stoppered collector stood with its dust charge about fifteen minutes and was weighed after the outside was wiped with a clean towel. In this way any water condensed on the outer surface, together with dust, was removed. In the field work hot water was unobtainable. After the residue from shaking out the shell with distilled water had been weighed *in situ*, it was wiped out with a clean towel and reweighed preparatory to the next dust collection.

Attempts to adapt cover slips to a shell for retaining permanent dust records were unsatisfactory, and 10 c. c. samples of the 100 c. c. suspensions preserved instead. Glassware, after being cleaned and rinsed, was kept in a dessicator. A chemical washbottle was used to wash down the dust deposit, the suspension shaken twenty-five times, poured out, and the rinsings added to 100 c. c. Of this suspension two samples of 1 c. c. each were pipetted into Sedgwick Rafter slides and counted as recommended in Standard Methods (8).

Fourth Series

(Comparison of Palmer and high-tension machines under field conditions.)

For the purpose of comparing the Palmer and high-tension machines, a large manufacturing plant using rubber offered its resources, and all of the subsequent field tests were done in its various departments and buildings. On a small rubber-tired truck was erected a wooden housing, sufficiently large to accommodate all the apparatus necessary to complete the determinations (Fig. 1). The first two tests showed the advisability of doing weighing and counting where vibration was not so evident.

Atmospheric conditions varied within very wide limits (Table IV). Some processes were productive of sufficient dust to warrant the use of respirators. Some were provided with exhaust hoods over the machines, while others were not. It is felt that for the purpose of comparing the two collectors the conditions were, therefore, sufficiently varied to warrant the drawing of definite conclusions.

Weighing and counting were done in a room set aside in the plant for this purpose. Determinations of total solids, and organic and inorganic fractions were done in the Department of Preventive Medicine, Harvard Medical School, where the samples were carried in clean 4-ounce tin-foil capped bottles with paraffined corks. Because of the varied character, solubility and color of the dusts encountered and the difficulty of making suitable standards for each (38), turbidity tests were not undertaken. Gooch crucibles proved unsatisfactory and beginning with sample No. 16 were replaced by the more reliable porcelain capsule. In the field tests, the amount of material remaining on the high-tension collector after removing the sample was large enough to be weighable, and, beginning with No. 10, three weight determinations were made in each test. Take for example, sample No. 10:

Test, No. 10

Wt. collector after 60 min. run	119.0185 gm.
Wt. collector before	118.7465
Increase in wt. of tube	0.2720 gm. (Table VI, Col. 1)
Wt. collector after 60 min. run	119.0185 gm.
Wt. collector after sample was rinsed out	118.7675
Wt. of sample (suspension)	0.2510 gm. (Table VI, Col. 2)
Sediment in 50 c.c. of suspension	.1045 gm. 2
Wt. of total in suspension	0.2090 gm. (Table VI, Col. 4)
Increase in wt. of tube	0.2720 gm.
Suspension sample	0.2510
Loss (left in tube)	0.0210 (Table VI, Col. 3)
Suspension sample	0.2510 gm.
Sediment in 50 c.c. sample	0.2090
Loss	0.0420 (Table VI, Col. 5)

The factors responsible for a gradual decrease in tube weight were not evidenced so far as the collecting surface was concerned, for the interior presented as mirror-like an appearance at the end of seventy-one tests as it did in the beginning. It is possible, however, that a small amount of inter-reaction occurred between the chemical dusts collected and the metal of the shell, which would result in loss in weight. Counts are reported as actually observed because the

figures (Table V) were used as a basis for percentage comparison. A correction was made for the particle content of the water used.

For convenience sake, the data of the seventy-one tests made in this series are tabulated together. Save when otherwise noted (Table IV), all tests were one hour long by stop-watch. The resulting weight figures for the high-tension machine were reduced proportionately to give equivalent values for 240 cubic feet per minute (Tables VI, VII). Talc room tests, Nos. 3–7 inclusive, were made in a room $36 \times 45 \times 11$ feet, in which there were eight cleaning hoods and two tumblers, only one of which was in use. The number of men at work varied from two to six. The tumbler gave rise to a large amount of talc dust. Tests Nos. 8 and 9 were taken in a blasting room, back of five operatives who were talc-blasting canvas shoes and steel heel moulds. A sand-blasting machine also added its quota of dust. This irregularly shaped room was about $48 \times 18 \times 11$ feet. Door and window conditions varied so much daily during the entire series that they were not summarized in any location.

One of the most striking facts observed in this series, and found continually afterwards in these tests, was the dissimilarity of the particles as shown in the two suspensions. This will be commented on later.

The next stand was in the carpenter shop near the planer used for surfacing cutting blocks. The collector truck was placed nearby. The operator, believing that the writer was after dust, cut his blocks dry, with a perfect rain of particles thrown against the collectors. The Palmer bulb opening upward, much adventitious heavy material settled in, giving the Palmer weights and counts higher values than those of the high tension. This dust was composed of wood fibre, whiting, talc, cloth fibre, etc., and in common with the carpenter shop series made later in the same room, but in a different location, tended to form a foamy suspension.

Because of the tremendous vibration only three tests were made in one of the main rooms of the factory, near a battery of cutting machines used to stamp out soles and other shoe parts. The dust here encountered was mostly a crude grade of whiting, which was liberally thrown on the cloth to prevent sticking of the layers in the cutter.

The rag house was 24×24 feet, and the bin room on the first floor where the tests were made was 12 feet high. Here were eight bins fed one at a time by a bucket chute. The tests were made during the shredding of waste cloth stock. The dust varied with the material fed, invariably being fibrous, and sometimes including inorganic substances as well.

The carpenter shop visited ($63 \times 41 \times 13$ feet) contained a Daniels planer, band saw, grind and emery wheels, surface and thickness planers, mortising machine and cross-cut saw, which worked as the need for them arose. Since only new stock was used in this shop, the dust encountered for the most part was from wood, save when cutting blocks were surfaced dry on the Daniels planer.

The foundry was in a building $62 \times 80 \times 27$ feet, wherein the activities of the twenty-seven men employed were divided between nine moulding benches, a core-breaking pen, aluminum and bronze furnaces and core-baking ovens. The collectors were installed near the core-breaking pen where most of the dust present originated. The number of men working here varied from two to five.

The grinding room measured $79 \times 31 \times 13$ feet, and contained four double-end naggers, three felt wheels coated with abrasive, a grinder head, four single and two gang drills. The naggers and abrasive wheels were fitted with downward suction apparatus. Many of the departments in which the air was sampled were fitted with exhaust hoods of various types. In this department aluminum, bronze and brass castings, chiefly boot and shoe forms, were trimmed to shape. Tallow liberally applied to the abrasive wheels tended to eliminate metallic dust. The dust sampled was similar to that of the foundry and was due to imperfectly removed cores.

The compound rooms tested differed in their shape, amount of ventilation, number of bins drawn upon, and amount and character of the substances used in making rubber stock. The dust encountered was essentially the same in both rooms, and similar to that encountered in the mixing room. The first compound room was $79 \times 20 \times 11$ feet; the second, $36 \times 38 \times 16$ feet; while the mill room was $100 \times 79 \times 12$ feet and contained sixteen mills in which rubber and other substances were mixed together.

TABLE V. — NUMBER AND DISTRIBUTION OF SIZE OF PARTICLES PER CUBIC FEET OF AIR

Test No.	High Tension					Palmer					Total per Cu. Ft.		Ratio	
	1	2	3	4	5	1	2	3	4	5	H	P	H = %P	P = %H
3	....	586	7,326	36,630	++	...	166	3,999	24,332	++	44,544	28,497	156.3	63.9
4	....	1,025	2,930	19,926	++	...	166	1,333	17,332	+	23,881	18,831	126.8	78.8
5	....	146	732	10,109	++	...	....	333	6,499	+	10,987	6,832	160.8	62.1
6	....	2,930	36,630	133,333	++	...	....	33,333	108,320	+	172,890	141,652	122	81.9
7	....	2,930	41,020	208,050	++	...	3,333	36,666	149,999	+	252,000	189,998	132.6	75.3
8	....	8,790	43,950	395,600	++	...	6,666	28,333	206,650	+	448,340	251,649	178.1	56.1
9	....	7,320	26,370	246,150	++	...	3,333	18,333	109,999	+	279,840	131,665	212.5	47
10	293	146	6,153	23,882	++	166	2,166	5,499	29,498	+	30,474	37,329	81.6	122.4
11	3,333	5,666	14,832	40,331	++	439	5,567	15,384	54,212	+	64,162	75,602	84.8	117.8
12	146	1,611	7,619	80,439	++	...	166	8,166	65,997	+	89,815	74,329	120.8	82.7
13	....	8,790	39,560	325,270	++	...	6,666	21,666	118,320	+	373,620	145,662	254.7	39.2
14	....	10,485	39,546	290,000	++	...	7,500	20,000	230,000	+	227,090	184,998	147	81.4
15	5,860	13,180	41,020	445,420	++	...	6,666	21,666	153,320	+	505,480	181,652	278.2	35.9
16	586	1,172	3,996	17,435	+	...	1,333	1,999	6,499	+	23,189	9,831	235.8	42.3
17	....	586	1,465	13,919	+	...	666	1,166	4,666	+	15,970	6,498	245.7	40.6
18	2,551	4,249	11,868	58,168	++	833	1,833	2,333	18,332	+	76,836	23,331	329.3	30.3
19	....	293	4,542	150,769	++	...	999	3,999	23,665	+	155,604	28,663	542.8	18.4
20	2,051	2,930	3,076	28,571	++	...	1,166	1,833	6,999	+	36,628	9,998	336.3	27.2
21	146	879	2,490	26,666	++	...	666	2,833	11,499	+	30,181	14,998	201.2	49.6
22	1,465	2,051	5,128	27,106	++	333	1,333	23,33	6,666	..	35,750	10,665	335.2	29.8
23	293	293	586	7,032	+	166	....	500	1,166	+	8,204	1,832	447.8	22.3
24	146	2,783	9,670	36,776	++	...	1,666	2,833	4,833	+	49,375	4,332	529	18.9
25	146	3,663	10,550	50,402	++	166	2,166	5,500	30,165	+	60,761	37,997	159.9	62.5
26	146	3,809	8,791	35,164	++	...	1,333	5,333	19,832	++	47,910	26,498	180.8	55.3
27	1,460	8,790	51,280	347,250	++	...	8,333	20,000	258,320	+	40,8780	286,653	142.6	70.1
28	....	4,688	10,256	38,388	++	166	1,666	6,666	39,665	+	53,332	48,163	110.7	90.3
29	439	2,051	8,351	35,311	++	333	2,000	3,166	7,333	+	46,152	12,832	359.6	27.8
30	....	586	4,395	13,772	++	...	500	2,000	3,166	+	18,753	5,666	330.9	30.2
31	1,904	5,128	8,500	31,941	++	833	1,833	6,000	22,000	+	47,473	30,666	154.8	64.5
32	146	2,051	7,179	30,622	++	333	1,500	3,000	19,665	+	39,998	24,498	163.2	61.2
33	146	3,956	7,326	23,296	++	...	2,000	3,500	11,166	+	34,724	16,666	208.3	47.9
34	....	3,956	17,875	177,142	+++	...	2,000	10,000	143,160	++	198,973	155,160	128.2	77.9
35	....	16,110	52,740	546,510	++	...	6,666	23,333	515,000	+	615,360	544,999	112.9	88.5
36	....	8,790	26,370	199,260	+++	...	5,000	11,666	145,000	++	234,420	161,666	145	68.9
37	1,460	5,860	29,300	222,710	++	...	....	10,000	158,320	+	259,330	168,320	154	64.9
38	293	2,930	6,007	58,461	+++	...	833	3,666	42,000	++	67,691	46,499	145.5	68.6
39	....	1,025	4,836	44,835	++	...	333	1,333	26,000	++	50,696	27,666	183.2	54.5
40	146	586	3,076	33,553	+++	...	333	1,000	20,332	++	37,361	21,665	172.4	57.9
41	....	732	3,369	44,981	+++	...	166	2,833	24,332	++	49,082	27,331	175.5	51.6
42	....	439	2,783	27,252	++	...	333	1,333	17,000	+	30,474	18,666	163.2	61.2
43	293	146	1,758	20,219	++	...	....	833	10,000	+	22,416	10,833	206.9	48.3
44	....	586	2,051	33,553	++	...	166	1,000	16,666	+	36,190	17,832	202.9	49.2
45	439	732	2,051	23,882	++	...	500	1,666	15,166	+	27,204	17,332	156.3	63.9
46	....	1,025	1,904	42,930	++	...	....	1,000	18,165	++	45,859	19,165	239.2	41.8
47	....	146	1,465	30,066	++	...	166	1,000	18,666	++	31,647	19,832	159.5	62.6
48	....	439	3,663	39,560	++	...	166	1,166	14,332	++	43,662	15,664	278.7	35.8
49	....	586	2,637	27,836	++	166	166	1,166	14,000	+	31,059	25,398	122.2	81.7
50	....	1,904	13,919	106,666	++	...	500	7,000	61,500	..	122,489	69,000	177.5	56.3
51	439	2,197	11,428	108,868	++	...	666	6,000	59,830	..	122,932	66,496	184.8	54
52	....	879	1,904	30,915	++	...	166	1,000	24,165	..	53,698	25,331	133	75.1
53	....	293	2,490	29,450	++	...	166	1,833	19,165	..	32,233	21,164	152.3	65.6
54	....	1,318	3,516	93,040	++	...	666	4,000	29,000	..	97,874	33,666	290.7	34.3
55	....	1,255	3,976	79,115	++	...	238	4,522	62,118	..	84,346	66,878	126.1	79.2
56	146	....	2,344	25,347	++	166	....	2,333	9,832	..	27,837	12,331	225.7	44.2
57	146	732	6,593	106,813	++	...	333	3,333	52,000	..	114,284	55,666	205.3	48.7
58	....	1,025	5,274	64,322	++	...	166	1,666	31,332	..	70,621	33,164	212.9	46.9
59	....	1,465	2,637	50,842	++	...	1,166	3,000	24,000	..	54,944	28,166	195	51.2
60	146	2,197	7,032	69,303	++	...	833	3,166	27,165	..	78,678	31,164	252.4	39.6
61	146	586	5,567	117,655	++	...	333	6,333	75,000	..	123,954	81,666	151.7	65.8
62	....	439	5,128	38,534	+	...	166	2,500	21,165	..	44,401	23,831	185	54
63	293	2,051	10,695	115,457	++	...	333	3,333	88,830	..	128,496	92,496	138.9	71.9
64	146	2,344	12,014	113,259	++	...	833	5,333	57,164	+	127,763	63,330	201.7	49.5
65	293	1,758	4,835	40,293	++	...	333	1,166	10,000	..	47,179	11,499	410.2	24.3
66	....	732	4,542	24,615	++	...	166	2,166	19,665	..	29,889	21,997	135.8	73.5
67	146	879	3,223	44,835	++	...	333	1,833	26,000	..	49,083	28,166	174.2	57.3
68	....	1,025	5,567	81,318	++	...	166	3,666	40,331	..	87,910	44,163	199	50.2
69	146	2,196	16,555	96,262	++	...	1,500	6,666	37,500	..	115,159	45,666	252.1	39.6
70	146	3,516	17,289	96,117	++	166	1,833	7,000	62,830	..	117,068	71,829	162.9	61.3
71	293	2,637	15,677	35,164	++	...	2,166	9,666	59,500	..	53,771	71,332	75.3	132.6
72	293	879	5,128	42,783	++	...	333	2,166	23,832	..	49,083	26,331	186.4	53.6
73	....	1,172	4,395	41,025	++	...	833	2,833	19,332	..	46,592	22,998	202.5	49.3

Discussion of Results

In Table V, the two suspensions were made up to 100 c. c. In counting some of heavier dusts 10 c. c. of this, in turn, was again diluted to 100 c. c. The proper factors for samples 14 and 55 were used, these being smaller (see Table IV) than the others in the series. In Class 5 (see Final Report on Standard Methods (8)) a single plus indicates the presence of many particles smaller than Class 4, a double plus means their marked concentration, while a triple plus indicates their very marked concentration. The percentage ratio of the total count per cubic foot for each test is commented on in the summary.

Due to factors not determined, the particulate matter in Palmer suspensions tends to form masses in which, by indirect lighting, different colored particles may be distinctly seen, which a similar sample collected by the electrical method will show as separate entities in the slide. This was particularly true of dusts in the compounding rooms examined. The observation is not confined to any one size of particles. It seemed, however, that the class covered by Column 5 tended to form aggregates to a greater numerical degree than did those of larger sizes. In counting, even where masses observed in Palmer suspensions were undoubtedly made up of smaller particles, they were regarded as single particles and classed according to their mass. Suspensions collected by other observers using the Palmer machine show in the reported photo-micrographs the same character of clumping so far as can be determined from the reproductions alone (39). As observed by the writer, the stippled effect brought about by these particles was much greater in the high-tension samples than can be accounted for by the greater number of cubic feet of the latter.

In the writer's experience the frequency with which this observation was met warrants the belief that counts made on Palmer machine suspensions, particularly so far as size classification is concerned, must be accepted with some reserve. For this reason also a comparison of percentage distribution of particles according to size would offer data of questionable value in this report.

Of the remainder of the original 100-c. c. suspensions, 50 c. c. were pipetted after thorough shaking into porcelain crucibles and evaporated to dryness This method of transferring material is felt to be responsible for the figures in Table VI, Column 5. It is difficult to withdraw, even with careful manipulation, a representative sample because of the difference in weight of particles in the same sample, many of which tend to settle quickly and be drawn into the pipette. This would account for the occasional instances where the total sediment figures obtained by doubling the weight of sediment in the 50 c. c. high-tension sample (Column 4) apparently exceeded the weight of sediment in the 100 c. c. samples (Column 2), or even that actually collected (Column 1). These experimental errors are indicated by plus signs in Column 5.

The figures in Columns 9, 10, and 11, Table VI, are twice those obtained from the Palmer sediment 50 c. c. sample. Those of Column 4 are twice the amounts found in the 50 c. c. high-tension sample. These figures and the O and I values as determined from the crucible weights, were multipled by the fraction 240 ÷ 273 to get the figures of Columns 6, 7, and 8, which are thus comparable with the Palmer figures. The proper correction was made for tests 14 and 55 (Table IV). The percentage relationship in both H and P figures of inorganic residue (I) to total sediment (S) in Columns 12 and 13 reveal how closely the larger quantities of dust collected by high tension corresponded to that obtained by the Palmer method.

The dried crucible was ignited over a blast lamp and the residue reported as inorganic (I) and the loss of weight as organic (O). While this procedure may have reduced possible sulphates and carbonates to oxids, the loss therefrom not to be strictly regarded as from organic material, the fact that both sediments were collected at the same time and treated similarly is regarded as warranting their being reported as comparable fractions.

In Table VII are compared the total sediment, organic and inorganic sediments in milligrams per cubic foot of air, together with percentage comparisons. The figures were obtained by dividing those in Columns 6 to 11 inclusive, Table VI, by 240, and expressing the results in milligrams.

One observed factor of possible importance in explaining the difference in results of the use of the two machines is the different way in which each would react to fluctuations in current. A slight drop in

TABLE VI.—COMPARISON OF HIGH-TENSION (H) AND PALMER (P) TOTAL (S) ORGANIC (O) AND INORGANIC (I) SEDIMENT WEIGHTS IN GRAMS

Actual Weights, High-Tension Tests						Sediment Collected in 240 Cu. Ft. Air						Ratio I to S	
						High Tension			Palmer				
No.	Tube Weight Increase 1	Water Sample 2	Difference Cols. 1 & 2 3	Total Sediment (S) 4	Difference Cols. 2 & 4 5	S 6	O 7	I 8	S 9	O 10	I 11	H 12	P 13
3	.0243	....	....	.02	....	.0087	.0028	.0059	.0048	.0026	.0022	67.8	45.8
4	.0177	....	....	.0104	....	.0045	.002	.0025	.0045	.0012	.0033	55.5	73.3
5	.0123	....	....	.0086	....	.0037	.0015	.0021	.0032	.0013	.0019	56.7	59.3
6	.1415	....	....	.1068	....	.0469	.0036	.0433	.0349	.0037	.0322	92.3	92.2
7	.1462	....	....	.1164	....	.0511	.0043	.0468	.0326	.0026	.03	91.5	92
8	.257	....	....	.2048	....	.09	.0027	.0872	.0593	.0072	.0521	96.8	87.8
9	.137	....	....	.1186	....	.0521	.0072	.0448	.042	.0052	.0368	85.9	87.6
10	.272	.251	−.021	.209	−.042	.0918	.0527	.0391	.1193	.0596	.0597	42.5	50
11	.133	.1055	−.0275	.0946	−.0109	.0415	.0409	.0006	.0515	.0506	.0009	1.4	1.7
12	.1415	.1325	−.009	.1008	−.0317	.0443	.0023	.0419	.0266	.0009	.0257	94.5	96.6
13	.2255	.2188	−.0067	.1994	−.0194	.0876	.0123	.0752	.0322	.0013	.0319	85.8	99
14	.2383	.2385	−.0058	.217	−.0155	.1429	.0265	.1164	.078	.0063	.0732	81.4	92
15	.345	.338	−.007	.2976	−.0404	.1308	.0139	.1168	.0597	.0065	.0532	89.2	89.1
16	.0278	.0243	−.0035	.023	−.0013	.0101	.0082	.0018	.0035	.0018	.0017	17.8	48.5
17	.017	.0115	−.0055	.011	−.0005	.0057	.0031	.0025	.0022	.0015	.0007	43.8	31.8
18	.0455	.0437	−.0018	.043	−.0007	.0189	.016	.0028	.0087	.0064	.0023	14.8	26.5
19	.0858	.0783	−.0075	.0766	−.0017	.0336	.0253	.0083	.0137	.0042	.0095	24.7	69.3
20	.0338	.0278	−.006	.0318	+.004	.0148	.0099	.0049	.0057	.0044	.0013	33.1	22.8
21	.0205	.0188	−.0017	.0186	−.0002	.0081	.0055	.0026	.0036	.0014	.0022	32.3	61.1
22	.0412	.0412	....	.0366	−.0046	.016	.014	.002	.0062	.0061	.0001	12.5	1.6
23	.0062	.0047	−.0015	.0056	−.0009	.0025	.0014	.001	.0011	.0009	.0002	40	18.1
24	.0305	.0245	−.006	.022	−.0025	.0096	.0089	.0007	.0069	.0057	.0012	7.2	17.3
25	.0417	.0307	−.011	.027	−.0037	.0118	.0089	.0029	.01	.0084	.0016	24.5	16
26	.0235	.0156	−.0075	.0164	−.0004	.0072	.0066	.0005	.0056	.0054	.0002	6.9	3.5
27	.251	.2372	−.0138	.2306	−.0066	.1013	.0522	.0493	.0594	.0292	.0302	48.6	50.8
28	.042	.041	−.001	.0276	−.0134	.0121	.0101	.0019	.0114	.0092	.0022	15.7	19.3
29	.03	.03	....	.0248	−.0052	.0109	.0098	.001	.0065	.0056	.0009	9.1	13.8
30	.021	.014	−.0075	.0124	−.0016	.0054	.0045	.0008	.0047	.003	.0017	14.8	36.1
31	.043	.0385	−.0045	.043	+.0045	.0184	.0168	.002	.0116	.01	.0016	10.8	13.8
32	.02	.016	−.004	.017	+.001	.0074	.0059	.0014	.0042	.0025	.0017	18.9	40.4
33	.0275	.0275	....	.0222	−.0052	.0097	.0082	.0014	.0044	.0038	.0006	14.4	13.6
34	.1145	.1105	−.004	.11	−.0005	.0483	.0127	.1356	.0303	.0086	.0217	73.7	71.6
35	.167	.16	−.007	.1512	−.0088	.0664	.0175	.0488	.0438	.0135	.0303	73.4	69.1
36	.096	.0915	−.0045	.089	−.0025	.0391	.0104	.0286	.0253	.0069	.0184	73.1	72.7
37	.162	.1585	−.0035	.1478	−.0107	.0649	.0166	.0483	.0317	.0071	.0246	74.4	77.6
38	.057	.054	−.003	.053	−.001	.0232	.0061	.0171	.0144	.0037	.0107	73.7	74.3
39	.022	.022	....	.0216	−.0004	.0094	.0042	.0052	.0083	.003	.0053	55.3	63.8
40	.017	.017	....	.0188	+.0018	.0082	.0021	.006	.0057	.0029	.0028	73.1	49.1
41	.0265	.0275	+.001	.0292	+.0017	.0128	.0049	.0079	.0077	.0032	.0045	61.7	58.4
42	.0163	.0148	−.0015	.0168	+.002	.0073	.0038	.0035	.0051	.0025	.0026	27.9	50.9
43	.0105	.008	−.0025	.009	+.001	.0039	.0021	.0018	.0017	.0006	.0011	46.1	64.7
44	.0135	.013	−.0005	.0156	+.0026	.0068	.0034	.0034	.0056	.0026	.003	50	53.5
45	.0145	.012	−.0025	.0162	+.0042	.0071	.0035	.0036	.0049	.0027	.0022	50.6	44.8
46	.0188	.0173	−.0015	.019	+.0023	.0083	.0034	.0049	.0052	.0021	.0031	59	59.6
47	.011	.009	−.002	.01	+.001	.0043	.0022	.0021	.0036	.0018	.0018	48.8	50
48	.018	.0168	−.0012	.0166	−.0002	.0072	.0033	.0039	.0023	.0012	.0011	54.1	46.8
49	.0332	.0274	−.0058	.0246	−.0028	.0108	.0058	.005	.005	.0017	.0033	46.2	66
50	.0686	.047	−.0216	.0424	−.0046	.0186	.0164	.0021	.0123	.0033	.009	11.2	73.1
51	.058	.048	−.01	.0282	−.0198	.0211	.0086	.0125	.0116	.004	.0076	59.4	65.5
52	.0208	.0161	−.0047	.02	+.0039	.0087	.0045	.0042	.0046	.0024	.0022	48.2	47.8
53	.036	.0336	−.0024	.0302	−.0034	.0132	.0087	.0045	.0054	.0019	.0035	34	64.8
54	.0592	.0554	−.0038	.0522	−.0032	.0229	.0109	.0119	.0116	.0039	.0077	51.9	66.3
55	.0456	.0376	−.008	.0366	−.001	.0228	.0106	.0122	.0177	.0074	.0102	53.7	58
56	.0264	.0212	−.0052	.0202	−.001	.0088	.0054	.0034	.004	.0028	.0012	38.6	30.0
57	.0462	.0402	−.006	.0574	+.0172	.0252	.0078	.0174	.0099	.0031	.0068	69	68.6
58	.0365	.0316	−.0049	.0294	−.0022	.0129	.0078	.005	.007	.0031	.0039	38.7	55.7
59	.0312	.0312	....	.0296	−.0016	.013	.0068	.0061	.0075	.0033	.0042	46.9	56
60	.0384	.035	−.0034	.0268	−.0082	.0161	.0065	.0096	.0082	.0035	.0047	59.6	57.3
61	.0705	.064	−.0065	.0618	−.0022	.0271	.0081	.0189	.0155	.004	.0115	69.7	74.1
62	.0296	.0268	−.0028	.028	+.0012	.0123	.0072	.005	.0076	.0022	.0054	40.6	71
63	.0968	.087	−.0098	.0882	+.0012	.0387	.0126	.0261	.016	.005	.011	67.4	68.7
64	.0622	.06	−.0022	.0582	−.0018	.0255	.0109	.0145	.0137	.0057	.008	56.8	58.3
65	.019	.0178	−.0012	.015	−.0028	.0065	.0022	.0043	.0054	.0024	.003	66.1	55.5
66	.0122	.012	−.0002	.0186	+.0066	.0081	.0034	.0047	.0039	.0023	.0016	58	41
67	.0158	.0048	−.001	.0172	+.0024	.0075	.0025	.005	.0067	.0038	.0029	66.6	42.2
68	.0288	.0263	−.0025	.027	+.0007	.0118	.0035	.0083	.0071	.0031	.004	70.3	56.3
69	.0568	.053	−.0038	.056	+.003	.0246	.0094	.0151	.0131	.0061	.007	61.3	53.4
70	.0914	.0884	−.003	.0894	+.001	.0392	.0167	.0225	.0203	.0092	.0111	57.3	54.6
71	.1005	.097	−.0035	.092	−.005	.0404	.0257	.0146	.025	.0162	.0088	36.1	35.2
72	.0182	.0177	−.0005	.0198	+.0021	.0087	.004	.0046	.0055	.0028	.0027	52.8	49
73	.0166	.0145	−.0021	.014	−.0005	.0061	.0019	.0042	.0056	.0025	.0031	68.8	55.4

TABLE VII. — TOTAL (S), ORGANIC (O), AND INORGANIC (I) RESIDUE, HIGH TENSION (H) AND PALMER (P), IN MILLIGRAMS PER CUBIC FOOT OF AIR

	S				O				I			
No.	H	P	H = % P	P = % H	H	P	H = % P	P = % H	H	P	H = % P	P = % H
3	.0362	.02	181.0	55.2	.0116	.0108	107.4	93.1	.0246	.0091	270.3	36.9
4	.0174	.0187	93	107.4	.0083	.005	166	60.2	.0104	.0137	75.9	131.7
5	.0155	.0133	116.5	85.8	.0062	.0054	114.8	87	.0087	.0079	110.1	90.8
6	.1954	.1454	134.3	74.4	.015	.0154	97.4	102.6	.1804	.1341	134.5	74.3
7	.2129	.1358	156.7	63.7	.0179	.0108	165.7	60.3	.195	.125	156	64.1
8	.375	.247	151.8	65.8	.0112	.03	86.1	116	.3633	.217	167.4	59.7
9	.217	.175	124	80.6	.03	.0216	138.8	72	.1866	.1533	121.7	82.1
10	.3825	.497	76.9	129.9	.2195	.2483	88.4	113.1	.1629	.2487	65.5	152.6
11	.1729	.2145	80.6	124	.1704	.2108	80.8	123.7	.0025	.0037	67.5	148
12	.1845	.1108	166.5	60	.0095	.0037	256.7	38.9	.1745	.107	163	61.3
13	.365	.1341	272.1	36.7	.0512	.0054	948.1	10.5	.3133	.1329	235.7	42.4
14	.523	.3312	157.9	63.3	.0972	.0266	365.4	27.3	.4263	.305	139.7	71.5
15	.545	.2487	219.1	46.6	.0579	.027	214.4	46.6	.4866	.2216	219.5	45.5
16	.042	.0145	289.6	34.5	.0341	.0075	454.6	21.9	.0075	.007	107.1	93.3
17	.0237	.0091	260.4	38.3	.0129	.0062	208	48	.0104	.0029	358.6	27.8
18	.0787	.0362	217.4	45.9	.0666	.0266	250.3	39.9	.0116	.0096	120.8	82.7
19	.14	.057	245.6	40.7	.1054	.0175	602.2	16.6	.0345	.0395	87.3	114.4
20	.0616	.0237	259.9	38.4	.0412	.0183	225.1	44.4	.0204	.0054	377.7	26.4
21	.0337	.015	224.6	44.5	.0229	.0058	394.8	25.3	.0108	.0091	118.6	84.2
22	.0666	.0258	258.1	38.7	.0583	.0254	229.5	43.5	.0083	.0004	2075	4.8
23	.0104	.0045	231.1	43.2	.0058	.0037	156.7	63.7	.0041	.0008	512.5	19.5
24	.04	.0287	139.3	71.7	.037	.0237	156.1	64	.0029	.005	58	172.4
25	.0491	.0416	118	84.7	.037	.035	105.7	94.5	.012	.006	181.8	55
26	.03	.0233	128.7	77.6	.0275	.0225	122.2	81.8	.0204	.0008	2550	3.9
27	.422	.2475	170.5	58.6	.2175	.1216	178.8	55.9	.2054	.1258	163.2	61.2
28	.0504	.0475	106.1	94.2	.042	.0383	109.6	91.1	.0079	.0091	86.8	115.1
29	.0454	.027	168.1	59.4	.0408	.0233	175.1	57.1	.0041	.0037	110.8	90.2
30	.0225	.0195	115.3	86.6	.0187	.0125	149.6	68.8	.0033	.007	41.7	212.1
31	.0766	.0483	158.5	63	.07	.0416	168.2	59.4	.0083	.0066	125.7	79.5
32	.0308	.0175	176	58.8	.0245	.0104	235.5	42.4	.0058	.007	82.8	120.6
33	.0404	.0183	220.7	45.2	.0304	.0158	192.4	51.9	.0058	.0025	232	43.1
34	.2012	.1262	159.4	62.7	.0529	.0358	147.7	67.6	.1483	.0904	165	60.9
35	.2766	.1825	151.5	65.9	.0729	.0561	129.9	76.9	.2033	.1262	161	62
36	.1629	.1054	154.5	64.7	.0433	.0287	150.8	66.2	.1191	.0766	155.4	64.3
37	.2704	.132	204.8	48.8	.0691	.0295	234.2	42.6	.2012	.1025	196.2	50.9
38	.0966	.06	161	62.2	.0254	.0154	164.9	60.6	.0712	.0419	169.9	58.8
39	.0391	.0345	113.3	88.2	.0175	.0125	140	71.4	.0216	.022	98.1	101.8
40	.0341	.0237	143.8	69.5	.0087	.012	72.5	137.9	.0291	.0116	250.8	39.8
41	.053	.032	165.6	60.3	.0204	.0133	153.3	65.1	.0329	.0187	175.9	56.8
42	.0304	.0212	143.3	69.7	.0158	.0104	151.9	65.8	.0145	.0108	134.2	74.4
43	.0161	.007	203	43.4	.0087	.0025	348	28.7	.0074	.0045	164.4	60.8
44	.0283	.0233	121.4	82.3	.0141	.0108	130.5	76.5	.0141	.0124	113.7	87.9
45	.0295	.0204	144.6	69.1	.0145	.0112	129.4	77.2	.0149	.0091	163.7	61
46	.0345	.0216	159.7	62.6	.0141	.0087	162	61.7	.0204	.0129	158.1	63.2
47	.0179	.015	119.3	83.7	.0091	.0075	121.3	82.4	.0087	.0074	117.5	85
48	.03	.0095	315.7	31.6	.0137	.005	274	36.4	.0162	.0045	360	27.7
49	.045	.0208	216.3	46.2	.0241	.007	344.2	29	.0208	.0137	151.8	65.8
50	.0775	.0512	151.3	66	.0681	.0137	497	20.1	.0087	.0374	23.2	429.8
51	.0879	.0483	181.9	54.9	.0358	.0166	215.6	46.3	.052	.0316	164.5	60.7
52	.0362	.0191	189.5	52.7	.0187	.0099	188.8	52.9	.0174	.0091	191.2	52.2
53	.055	.0225	244.4	40.9	.0362	.0079	458.2	21.8	.0187	.0145	128.9	77.5
54	.0954	.0483	197.5	50.6	.0454	.0165	275.1	36.3	.0495	.032	154.6	64.6
55	.0878	.0775	113.2	88.2	.0406	.0325	124.9	80	.0472	.045	104.8	95.3
56	.0366	.0166	220.4	45.3	.0224	.0116	193.1	51.7	.0141	.0049	287.7	34.7
57	.105	.0412	254.8	39.2	.0324	.0291	111.3	89.8	.0724	.0283	255.8	39
58	.0537	.0291	184.5	54.1	.0324	.0291	111.3	89.8	.0208	.0162	128.3	77.8
59	.0541	.0312	173.3	57.6	.0283	.0137	206.5	48.4	.0254	.0174	145.9	68.5
60	.067	.0341	196.4	50.8	.027	.0145	186.2	53.7	.0399	.0195	204.6	48.8
61	.1129	.0645	175	57.1	.0337	.0166	203	49.2	.0787	.0479	164.3	60.8
62	.0512	.0316	162	61.6	.0299	.0091	328.5	30.4	.0208	.0224	92.8	107.6
63	.1612	.0666	242	41.3	.0524	.0208	251.9	39.6	.1087	.0457	237.8	42
64	.1062	.057	186.3	53.6	.0454	.0237	191.5	52.2	.0604	.0333	181.3	55.1
65	.027	.0225	120	83.3	.0091	.0099	91.9	108.7	.0179	.0124	144.3	69.2
66	.0337	.0162	208	48	.0141	.0095	148.4	67.3	.0195	.0066	295.4	33.8
67	.0312	.0279	111.8	89.4	.0104	.0158	65.8	151.9	.0208	.012	173.3	57.6
68	.0491	.0295	166.4	60	.0145	.0129	112.4	88	.0345	.0166	207.8	48.1
69	.1025	.0545	188	53.1	.0391	.0254	153.9	64.9	.0629	.0291	216.1	46.2
70	.1633	.0845	193.2	51.7	.0695	.0383	181.4	55.1	.0937	.0462	202.8	49.3
71	.168	.1041	161.3	61.9	.107	.0675	158.5	63	.0608	.0366	166.1	60.1
72	.0362	.0229	158	63.2	.0166	.0116	143.1	69.8	.0191	.0112	170.5	58.6
73	.0254	.0233	109	91.7	.0079	.0104	75.9	131.6	.0175	.0129	135.6	73.7

potential would cause a drop in the Palmer manometer gauge, often as high as ½ cubic foot per minute, whereas the tone of the high-tension fan motor would hardly be altered, nor would, moreover, such a slight line drop show itself in the intensity of the corona discharge.

It has been shown that some of the finer particles may pass through the Palmer apparatus. In the only efficiency tests reported (38), carmine and pearl dust were used. Tests with the latter covered a period of about five minutes, in which time but little of the pearl dust used would have a chance to become fixed to the inside of the glass with resulting loss, as observed in runs of an hour's duration. It is to be expected that pearl dust, insoluble in water, and containing particles as large as those passing through bolting cloth would, under the conditions reported, be almost all washed out in recovery. It is felt, therefore, that these tests of the efficiency of the Palmer apparatus are not sufficiently conclusive.

It is possible on the contrary to determine the efficiency of a high-tension collector through the application of artificial dust charges by noting the increase in weight of the collector. It is further possible through using aluminum foil instead of tubing to reduce the weight of the collector as compared to the dust charge (20). Again, after all the sediment that can be so removed has been washed down by a wash bottle with a fine jet and the collector dried, the weight of material left on the walls can be determined. The ratio between the original increase in weight of the tube, the reweigh figure just referred to and the weight cleaned, will give an accurate idea as to what percentage of dust actually present in the air was collected, and what was lost.

It is comparatively an easy matter to produce water relatively free of particulate matter by distillation with subsequent settling or filtration through a Berkefeld candle. For use in the Palmer apparatus but few liquids approach it in availability or ease of preparation. On the other hand, water is of questionable value in making Palmer tests in low temperatures, as has been the writer's experience. This objection is not encountered with the use of the high-tension method.

There is a tendency on the part of the Palmer machine to subject the passing air to irregular treatment as shown by the variable size of the air bubbles. While such a device would introduce another factor to be reckoned with, and hence be of disadvantage, it is suggested that the incoming air might to advantage be broken up into smaller bubbles by passing it through a perforated porcelain plate. It may also be possible that the intermittent passage of air through the Palmer bulb may not carry with it the less responsive particles of dust due to their greater inertia, whereas through the high-tension collector the passage of air with its dust content is smooth and continual.

Another factor of importance is the personal element necessary in keeping the manometer gauge registering a uniform rate of air passage through the bulb. Slightly more than 40 c. c. (15) dust-free distilled water is necessary to cause the fan to register 4 cubic feet per minute at the start. This quickly tends to decrease, requiring the frequent addition of small portions of water. Several tests were discarded because of certain mechanical defects encountered in the apparatus.

The only trouble encountered in the maintenance of the high-tension apparatus used was the occasional replacing of brushes and truing the commutator. After several days' run the commutator segments became pitted at points corresponding with the flow of current to the rectifier and in this condition commutator arcing was noted, with very marked reduction in the intensity of the corona.

The factors responsible for the disparity of results obtained in using the two machines side by side were not determined. In part, at least, those already referred to, which were encountered in the progress of this work, may be responsible.

Summary of Fourth Series

Table VIII summarizes the seventy-one tests, reported by departments and buildings, and indicates something of their relative dustiness. Columns 3 and 4 contain the total amounts of dust collected for each department (Col. 1) for the number of tests conducted therein (Col. 2). Columns 8, 9, and 10 indicate the average per location in grams. The total dust collected is shown together with the average for the seventy-one tests. The high-tension machine collected in the entire series 58.66 per cent. more than the Palmer, i. e., the latter col-

lected under the same conditions but 63.0 per cent. of the amounts precipitated by high tension.

Table III shows for a series of experimental charges an average return of 96.1 per cent. The dust content of the room used was, for the small amount of air passed, a negligible quantity. A larger series, with careful application, control of air currents, and variable amounts of different materials may yield a higher figure (see Second Series). The tables suggest that a certain percentage of material is lost, which percentage is, within limits, a relatively constant figure whether small (50 mg.) or larger (100 and 200 mg.) charges be used.

The findings in Table V may be summarized as follows:

Total H particles per cu. ft., 71 tests	7,446,996
Average, 71 tests	104,887
Total P particles per cu. ft., 71 tests	4,461,334
Average, 71 tests	62,835
H = % P	166.9 %
P = % H	59.9 %

In many Palmer dust samples, agglomerates were encountered, very evidently made up of smaller particles. These were counted according to mass, otherwise the number of particles undoubtedly would have been larger. The high-tension suspensions invariably presented an evenly distributed, uniform appearance.

In Table VI the high-tension figures summarize as follows:

Total tube weight increase	4.7824 gm.
Average, 71 tests	.0673 gm.
Total sample weights	3.7395 gm.
Average, 64 tests	.0584 gm.
Total sediment weights	4.0998 gm.
Average, 71 tests	.0577 gm.
Average sample weight = % average tube weight	86.7 %
Average sediment weight = % average sample weight	98.8 %
Average sediment weight = % average tube weight	85.7 %

As a result of experiments in Table III, 96.1 per cent. of artificial dust charges were retained. If in the subsequent processing the dried total sediment represents 85.7 per cent. of the dust caught on the precipitator, and we assume the efficiency of the high-tension machine, based on Table III, to be 96.1 per cent., then the total sediment obtained by evaporation, on the basis of this comparison, represents 82.3 per cent. of the dust in the original air sample.

In Table VII the total weight in milligrams per cubic foot of air summarizes as follows:

Total Weights		Average, 71 Tests	H = % P	P = % H
HS	7.6959	.1069	S: 157.9	S: 63.3
PS	4.8134	.0677		
HO	2.7064	.0381		
PO	1.8095	.0254	O: 150.0	O: 66.6
HI	5.3875	.0758		
PI	2.9818	.0419	I: 177.3	I: 55.2

On the basis of the comparisons here reported, the Palmer figures in terms of high-tension returns are as follows:

	Table V	Table VII			Table VIII	Average
	Counts	S	O	I		
P = %H	59.9 %	63.3 %	66.6 %	55.2 %	63.0 %	61.6 %

The high-tension figures in terms of Palmer returns are as follows:

	Table V	Table VII			Table VIII	Average
	Counts	S	O	I		
H = %P	166.9	157.9	150.0	177.3	158.6	162.1

Applying the same criterion to the Palmer sediment values, if the Palmer shows a relative efficiency of 61.6 per cent. as compared with the high-tension machine, then we are justified in assuming that Palmer sediment values, as recovered in the crucible, represent but $61.6 \times 82.8 = 50.69$ per cent., or a little over half the actual dust present in the air sampled.

It is realized that the experiments reported are few in number (71), and that a much larger series may yield widely different average figures.

In using the Palmer apparatus there is always an indeterminable amount of dust which may fall into the bulb, yielding data which cannot be consistently compared with the amount which might enter the human breathing passages with their ascending nares. (Compare tests 10 and 11, Table VI.)

The type of high-tension machine used is far too bulky for ordinary field work, and until simplified, the Palmer represents the best method of dust collection for its purpose that we now have (8, 38). The higher values obtained with electrical precipita-

tion, together with the absence of certain objections to the Palmer method, leads to the belief that the former warrants further study.

Moreover, with increasing industrial installations for by-product recovery, it is conceivable that a simplified form of apparatus may be advantageously developed to run on the larger installations, by which the sanitary quality of the air may be studied throughout the plant.

For field work, a simplified apparatus has suggested itself to the writer and would include a small motor generator, such as used for electro-therapeutic purposes, which would furnish alternating current and at the same time run a standardized centrifugal fan. The transformer could be of the closed core type having the proper winding ratio, and could be air-cooled from the fan exhaust. A kenotron could be used to take the place of the mechanical rectifier (20), and the whole apparatus including a light aluminum collector and conveyor duct be made thus portable and practical (40).

The electrical precipitation apparatus, as used in this study, is far too bulky for ordinary field work, but can easily be simplified and made portable.

The method of electrical precipitation has certain advantages over the Palmer, viz.:

(a) Absence of suspending medium.
(b) Uninterrupted passage of air.
(c) Facility of determining the percentage of dust present in the air in the sample studied, and the percentage of air dust represented by the weight of total sediment.

These conclusions seem to warrant further study of electrical precipitation of dust as applied to the sanitary analysis of air.

TABLE VIII. — SUMMARY OF FOURTH SERIES BY DEPARTMENTS

Department	No. of Tests	Total HS 240 gm.	Total PS 240 gm.	Difference	H = % P	P = % H	Average per Location		
							H 240	P 240	Difference
1	2	3	4	5	6	7	8	9	10
Talcum	7	.2567	.1813	.0754	141.58	70.62	.0366	.0259	.0107
Daniels planer	2	.1333	.1708	.0375	78.04	128.13	.0666	.0854	.0188
Cutting machines	3	.2273	.1118	.1155	203.3	49.18	.0757	.0372	.0385
Rag house	9	.2405	.1144	.1261	110.22	47.56	.0267	.0127	.014
Carpenter shop	10	.1938	.1249	.0689	155.16	64.44	.0193	.0124	.0069
Foundry	7	.2595	.1595	.1	162.69	61.46	.037	.0227	.0143
Grinding	8	.0577	.0361	.0216	159.83	62.56	.0072	.0045	.0027
Compounding	8	.1201	.0669	.0532	179.52	55.7	.015	.0083	.0067
Mixing	8	.1708	.0854	.0854	200	50	.0213	.0106	.0106
Compounding	9	.0977	.0565	.0412	172.92	57.88	.0108	.0062	.0046
Total	71	1.7574	1.1076	.6498					
Average		.0247	.0154	.0091	158.66	63			

Conclusions

The electrical precipitation method of dust collection in this series showed 62.1 per cent. greater average returns than the Palmer water spray sampler, for the same amount of air and under identical conditions.

The Palmer suspensions can give factitious counts because of agglomeration of particles in aqueous suspension. For this reason the actual number of particles present may be higher than those reported.

The writer wishes to express his indebtedness to Professor M. J. Rosenau, of the Department of Preventive Medicine and Hygiene, Harvard Medical School, for his many suggestions and kindly criticisms. Thanks are due Miss Lila M. Spence who made the chemical determinations here reported.

To the many officials and employees of the corporation which made possible the field work — men whose names are not mentioned at their own request — the writer is particularly indebted for their splendid spirit of co-operation, shown often with much personal inconvenience to themselves. Without their assistance the field work here reported could not have been done.

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APPLICATIONS OF PSYCHIATRY TO INDUSTRIAL HYGIENE*

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WE are nowadays being constantly reminded that we stand on the threshold of a reconstruction period. Warnings and advice emanate from varied sources — statesmen, financiers, industrial leaders and unemployed workers. A glance at the daily papers shows us that social unrest and industrial discontent are problems of immediate importance. A study of the more technical literature in the fields of political economy, education, industrial management, psychology, medicine, and social service, shows that a great many people are thinking, and thinking intelligently, about these problems. The hopeful aspect of the situation is that, whether the point of view is that of the industrial manager trying to reduce labor turnover or that of the physiologist investigating fatigue, there is shown a feeling of broad humanitarianism, a desire to understand each member of the industrial system as an individual, and a reaction against the old system of exploiting labor to produce wealth.

It is in just this field of understanding, the individual worker and his reaction, that psychiatry is of use. Carleton Parker (1) even goes so far as to say that: "Modern labor unrest has a basis more psychopathological than psychological, and it seems accurate to describe modern industrialism as mentally insanitary." Some causes of this mentally insanitary condition are brought out by Marot (2) in a book entitled *Creative Impulse in Industry*. Modern business enterprise and machine technology are said to have extinguished the joy of the creative experience; craftmanship is a thing of the past; an article owes its existence to an infinite number of persons, and a worker's claim to the product of his labor is merged in an infinity of claims which totally impersonalizes the industry. The worker has become a mere factory attachment, and surrenders himself to the rhythm of the machine. Thus creative desire has been lost and the only reason left for laboring is the predatory desire to possess wealth — to get paid off and to do as little work as possible for as large a reward as possible. But this is only one of many difficulties. Among the economists, Parker has been the pioneer and has most vigorously preached the necessity of understanding human behavior, and especially industrial behavior, from an individual standpoint. In his paper, *Motives in Economic Life* (1) he says: "We economists speculate little on human motives. We are not curious about the great basis of fact which dynamic and behavioristic psychology has gathered to illustrate the instinct stimulus to human activity. Most of us are not interested to think of what a psychologically full or satisfying life is. . . . Our economic literature shows that we are but rarely curious to know whether industrialism is suited to man's inherited nature, or what man in turn will do to our rules of economic conduct in case these rules are repressive." When human motives are isolated, described, and compared, such phenomena as business confidence, the release of work energy, the decay of workmanship, decline in the thrift habit, and labor unrest may be analyzed with some intelligence. But the careless *a priori* deductions touching human nature which still dominate our orthodox texts must be discarded. As a substitute for the orthodox and vague concept of human nature Parker gives a list of "some sixteen instinct unit characters which are present under the laborer's blouse and insistently demand the same gratification that is, with painful care, planned for the college student."

In his analysis of the I. W. W. Parker (3) shows that thwarting these instincts and condemning the worker to a life of limited happiness, restricted personal development, and desolation when sick, brings about a state of mind which amounts to an industrial psychosis. He says the I. W. W. is purely a symptom, and can be "profitably viewed only as a psychological by-product of the neglected children of industrial America." In other words we

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must treat these "mentally insanitary" conditions not only by shortening hours and increasing pay, but by so educating the children that they will be able to use their time off in ways that give constructive satisfaction to the instinctive cravings we all have for gregariousness, productiveness, motherliness, exercise of initiative, acquisition, ostentation, etc.

Other economists are taking up a similar point of view: Taussig (4) has shown that the pay envelope is not a satisfactory motive for work — other satisfactions are equally or more important. Irving Fisher (5) looks forward to the day when we will have a truer understanding of the nature of human freedom, saying: "What we liberty lovers are really groping for is, apparently, not to do as we think we please, but to do what will actually please us after it is done; that is, to satisfy fairly well all of the great fundamental human instincts, of which there are many besides the instinct of self-preservation or of making a living. The workman not only longs for more pay, but he hungers and thirsts for other things which he cannot formulate, because so largely unconscious." Tead (6) sounds the same note in his discussion of labor unrest, saying that a considerable part of it is really pathological and "might be called a definite industrial psychosis." Veblen, Wolf and others are writing in a similar strain. So it appears that the economists are becoming psychiatrists and are showing the way to the physician. If the physician is to take his rightful place in developing the mental hygiene of industry he must forget orthodox psychiatry (as the economist seems to be forgetting cut and dried political economy) and interest himself in a dynamic, individual psychology which recognizes the essentials of human nature and at last begins to analyze for us the elements of which human nature really consists, looking on each case as a human experiment in reaction to environment.

Sarah Murphy, aged 43, Catholic, a fur sewer in a department store in Boston, comes into the out-patient department of the Massachusetts General Hospital complaining of pain and numbness of her right hand. She goes to the medical, neurological, and industrial clinics, and after several visits acquires the diagnosis of "Occupational Neurosis." The social service department then takes her in hand, and finds out that the numbness of her hand began at about the time her oldest son went to France. Just previous to his departure he had married a Protestant girl, and because of his mother's antagonism to the match, the ceremony had been secretly performed in a Protestant church and the mother had not been informed until afterwards. The patient was in the habit of getting breakfast and supper for her other two sons whom she was educating in technical schools. Beside this she worked all day at the store. On Sundays she was too tired to do anything, but dragged herself to church as a duty. It was found possible to send her away for a two weeks' rest, a scholarship was procured for one son, and a job for the other whereby he was enabled to pay for his own tuition. With this relief, and a superficial explanation that her trouble was due to work and worry, a cure was brought about.

Anyone interested in the psychogenesis of mental breakdowns can easily see the mechanism: the emotional shock of the older son's marriage taking the joy out of the mother's life; the feeling of self-pity arising from her long hours of work, the feeling that the situation was intolerable, and the inability to face this situation, all finally tended to bring about the hysterical escape through the development of her symptoms. This is exactly the mechanism we have become so familiar with in the war neuroses. And if the department store physician had been interested in psychiatric problems, a half hour's interview, a visit or two of the nurse to the home, and the cure would have been brought about expeditiously without recourse to the necessarily slow and cumbersome diagnostic machine of a great hospital; and both the store and the patient would have been saved some weeks of work. Such cases can be found everywhere, our wards and dispensaries are full of patients to whom the doctors apply long meaningless labels — "neurasthenia," "psychasthenia," "psychoneurosis" — and for whom they do little. By an investigation of the patient's personal problems, an understanding of the usual reactions of the human being, and by simple help in readjusting the patient to the environment, a great deal can be done.

It is not only the cases of illness that should be attacked in this way. Many people with similar unbearable situations do not develop the usual symptoms that we

recognize as illness. They merely become inefficient, restless, wander away from their jobs, or become radicals and bolshevists (7). Peabody (8) and his collaborators found an interesting example of this in the cases of Effort Syndrome studied at U. S. A. General Hospital No. 9. A striking number of the histories showed that in civil life these men drifted from one employment to another, never breaking down enough to consult a physician, but adding their number to the shifting, inefficient labor element so costly to employers. It took the rigor of army life, with no possibility of escape by moving on, to bring out their symptoms. Before these people have left their work or have been fired for inefficiency, they should be interviewed by someone competent to understand them and their probable troubles. At such times advice from a physician, the loan of some money, a visit to a sick child or wife, or any of the thousand possible personal and individual aids, might save the worker from becoming soured, keep him from joining the ranks of the discontented, and prevent the development of a litigant and paranoid personality. Employment managers are beginning to recognize these facts and are using various methods to alleviate the troubles: one firm employs a lawyer especially to watch the loan sharks and help out employees in financial difficulty. Others keep man-record charts (9) and watch carefully the workers' efficiency. Too often this is merely for purposes of sizing up the employee, but one firm has shown that frequently a drop in a man's efficiency can be traced to personal difficulties of a nature that can be helped.

So we get back to the necessity of understanding human nature and of giving to the fundamental human cravings an outlet. The instinct of self-preservation is partially satisfied with the pay envelope; welfare work helps to make possible satisfaction of the instinct of home-building; but with our present industrial system it is harder to see how the cravings for self-assertion, creation, excitement, and the like can be met. The atmosphere created by the division of labor and scientific management is repressive to all these instincts — the man may develop a feeling of inferiority, and unless given some outlet he will become discontented and get satisfaction through striking, drinking or other abnormal sublimation. These are mental problems and must be so looked upon by physicians interested in mental hygiene, but the whole problem is so complex that at present most industrial physicians will consider it more expedient to watch for the psychotic symptoms to appear in individuals and then do their best to treat them sympathetically in the light of their knowledge of industrial psychology.

The recent work done in the personnel department of the army has awakened wide interest in the possibility of applying mental tests to applicants for industrial positions. The ultimate aim is to fit the job to the man so well that discontent will be minimized and labor turnover reduced. Ball (10) advocates the establishment of laboratories for the thorough medical and psychological examination of all employees; he believes that in this way men can be fitted immediately to the right occupation, without the costly experiment of trial. Although his paper reads well, it is not convincing and the methods advocated seem generally impracticable. In the army work, however, the psychologists certainly showed that they could pick out the capable men by comparatively short group tests, and Ball gives outlines of similar tests. In a more restricted way mental tests have been applied in industry for some years. Jaques (11) had excellent results in choosing typists and stenographers for certain types of work by psychological tests, and the results of these tests correlated well with the output later shown by these employees. Lamb (12) also reports success in gaining better judgment for selection and placement of employees by intelligence tests. On the other hand, Kelly (13) exposes some fallacies of the army rating system, especially in its application to industry. Strictly speaking, these tests have psychiatric interest only when used for the detection of subnormal individuals, but they seem to be of value from the prophylactic standpoint in reducing misfits in the shops — and maladaptation to environment is the basis for many mental breakdowns. In the present state of our knowledge perhaps Johnson's (14) suggestion is the best: he recommends that factory training departments be installed in all plants as testing places for applicants for factory work. And he claims that by thus eliminating incompetent and unqualified candidates the morale

of the departments is kept at a higher level and labor turnover is decreased.

Fatigue is another subject that comes into the field of industrial psychiatry. A great deal of work has been done by physiologists on neuro-muscular fatigue, and by the psychologists on mental fatigue. Spaeth (15) has recently reviewed the whole subject thoroughly and brought the two points of view together. Though a biological physiologist, he has given the psychological element in fatigue its just due. He states that laboratory subjects and industrial subjects are absolutely incomparable units. He uses the term "industrial fatigue" for the daily and weekly weariness resulting from industrial work, and suggests the term "industrial psychoneurosis" for the "gradually accumulating fatigue of the over-driven industrial worker." Overwork, however, is not the fundamental cause of neurosis or psychoneurosis. These disorders are fundamentally emotional breakdowns due to lack of satisfaction with life, so the theory that the etiology is "gradually accumulating fatigue" is untenable. The symptoms may simulate fatigue, but neuro-muscular fatigue is cured by simple rest, and these conditions are not. "Industrial psychoneuroses" are simply neuroses with an occupational coloring due to the work in which the individual happens to be engaged.

The mechanism of such a neurosis is typically something like this: An individual is in an intolerable situation which he is constitutionally unable to dominate; the reaction of a neurosis sets in with depression of spirits, irritability, preoccupation, self-pity, etc., but a conventional cause for the decreased efficiency must be found to rationalize the situation, so the individual calls it overwork. Obviously with this idea of overwork in mind the symptom usually acquired is fatigue or asthenia, but frequently symptoms more closely associated with the work are developed, such as paralysis of parts of the body necessary for work, muscular pains making work impossible, tremors, or even epileptiform seizures. The case quoted above is an example of emotional breakdown from personal causes taking on an occupational symptomatology. The work may have determined the form of the symptoms but there is no evidence that it had much to do with the development of the trouble. Work may of course be an etiological factor, but not through so simple a mechanism as accumulated fatigue. Work that represses emotional cravings often brings out neuroses, just as satisfactory work is the greatest curative agent we have for these conditions. Let us no longer fool ourselves into thinking that overwork, *per se*, is the cause of mental breakdown.

To sum up, the problems of industrial psychiatry are:

A. Prophylaxis of mental breakdowns by adapting the worker to his environments, and eliminating causes of discontent.

B. Treating psychiatric cases when they arise in a rational way according to the facts of each case, and considering as psychiatric phenomena many forms of behavior that until recently have been given unsympathetic names, e. g., "the groucher," "the kicker," "the trouble maker," and "the hobo."

As conditions are at present, a reasonable application of psychiatry to industry would seem to be the following:

1. Physical examination of all applicants for work.

2. Mental examination by (a) a period of training and observation, or (b) through mental tests.

3. Keeping in personal touch with employees' individual problems by means of (a) good foremen, (b) a system for watching individual efficiency, or (c) a sympathetic staff with a psychiatric point of view in the employment management office, thus salvaging the men who might otherwise be fired.

4. Training the industrial physician to a knowledge of how human nature is constituted, not in conventional terms, but in the light of a dynamic and living psychology that considers the behavior of human beings in terms of instinctive sources of energy, integrated into motives, these motives needing outlet through energy transformation into *satisfactory* activity.

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FLATFOOT AND ITS PREVENTION*

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WHILE everyone admits the importance of strong feet, no systematic efforts have ever been made to correct the common and weakening disability popularly known by the general term flatfoot. The subject is, however, well worthy of the attention of public health officials and of employers of labor as well as of the public itself.

In Europe the problem of flatfoot has been considered by army surgeons, and its correction and prevention have long been a matter of gymnastic drill and shoeing; but in this country before the war flatfoot was a subject relegated to the consideration of a few specialists. Now that the war has shown the extent of foot weakness among Americans, the importance of the question cannot be denied. Indeed, it has been suspected for a long time by experts that the American people were becoming the most weak-footed people in the world. As recent figures seem to justify the suspicion, means should be taken to check this increasing and by no means despicable evil.

The importance of the subject is well recognized in the equipment of armies, and governments devote much care to the footwear of their soldiers. Little or no attention, however, is paid by the directors of factories, large department stores or railroads to the condition of the feet of their employees. And yet the standing capacity of workers is an important factor in efficiency, and fatigue is of importance in civil no less than in army life. The test of leg fatigue in war is more sharp than in the work of a clerk or a shop girl, but tired feet are tired feet, and detract from the serviceableness of either shop girl or soldier.

What the normal static foot strength should be in any individual is a matter of estimate based upon judgments formed from examination of an adequate number of cases, normal and abnormal, and no precise statement can be made defining the normal. It can, however, be assumed that individuals of average health should be able, with proper care of their feet, to engage in any ordinary occupation without foot distress. If they are unable to do so, the cause of their weakness should be determined, and in a large majority of cases it will be found to be due to improper footwear, either at their work or in the period before their work was undertaken. In this statement the small group of congenitally or paralytically deformed feet is not included, but attention is called to the large group of individuals who unwittingly injure their foot strength and cause themselves unnecessary discomfort.

The remedy for this widespread difficulty is to be sought by calling the facts to the attention of the shoe-wearing and shoe-purchasing public and to those whose business it is to shape, furnish and sell shoes. There is no doubt that the shoes commonly worn are the chief cause of foot weakness. Formerly shoes were made by cobblers and small manufacturers, and varieties in shape according to individual needs were possible. At present, however, shoes are made in large numbers under the direction of comparatively few people and the needs of the individual cannot be considered. The foot is shaped to the shoe more than the shoe to the foot. The excellence in appearance of footwear and its universal purchasability have made Americans not only a shoe-wearing people, but a factory-made shoe-wearing people. Undoubtedly barefooted people are stronger footed, but Americans will never become a barefooted people.

A number of Chicago citizens who volunteered for enlistment at the outbreak of the Spanish-American War were photographed naked and the picture was published in a medical journal by the examining surgeon as showing fine types of American manhood. The picture in question displays a remarkable collection of healthy and well-proportioned men, all standing in a markedly weak-footed, knock-ankled and splay-footed position. Their condition would have practically incapacitated them for efficient marching. If, in comparison with this, any photograph of a standing group of naked South Sea Islanders or Africans be examined, the contrast in evident foot strength of the

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otherwise physically inferior barefooted savages is striking and noteworthy. Moreover, it appears to be true that there has been no improvement in American foot conditions since the Spanish War.

The result of the physical examination of the first million draft recruits (Jour. Amer. Med. Assoc., 1919, 73, 272) showed,

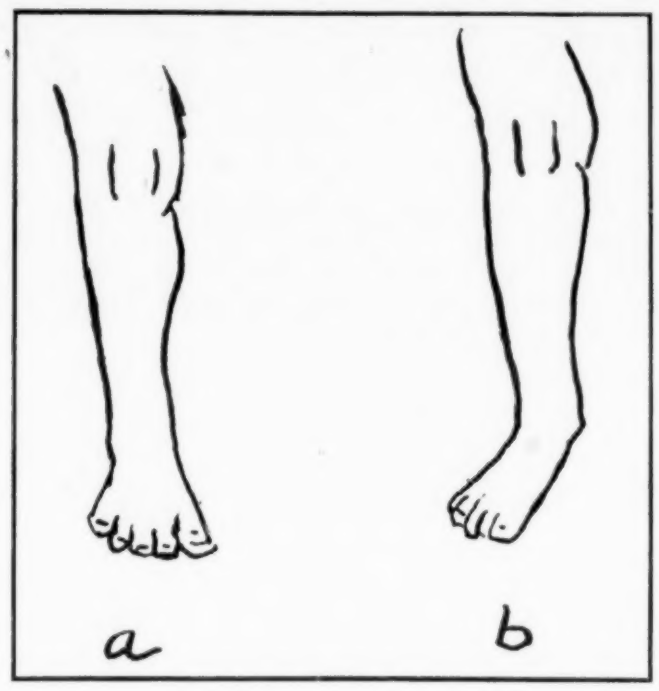

FIG. 1. — (a) Strong static position; weight falling over middle line of bony structure of foot. (b) Weaker static position; weight falls inside mid-foot line, causing strain on inner ligaments.

among other interesting facts, " the overwhelming predominance of flatfoot as a physical defect. The condition was found in the ratio of 177.45 per 1000, or nearly eight times as many as any other defect." . . . " The comparison between men coming from rural districts is also interesting. The amount of flatfoot from the Southern states is markedly less than that from the Northern states. Probably the mildness of the climate and the general practice of negroes and boys — especially among the rural classes — of going barefoot is responsible for the better development of the feet, and consequently for the smaller percentage of flatfoot in the South."

In static flatfoot (plano valgus) — a deformity characterized by the falling in and down of the ankle and the middle of the foot — the front mid-line of the foot points outward instead of following the mid-line of the leg, and the weight-bearing strength of the foot is lessened as the body weight comes unduly on certain non-weight-bearing structures. There is no question that this deformity is the result of footwear, and the need of reform in shaping shoes is clear.

The reduction of the strength of nearly eighteen men in every hundred is a heavy tax to pay for a lack of wisdom in shaping and buying shoes. Furthermore, there are other shoe deformities than flatfoot, *viz.*, distortion of the toes, weakening of the toe grip upon the ground, and the spread of the front of the foot, all of which, while causing little trouble ordinarily for light workers, are handicaps for heavy laborers or for persons who have to stand for long hours.

An examination of American shoe lasts shows a common disregard of the evident fact that the inner side of the front of the foot is much higher along its whole line than the outer side, when the foot is placed in the strong weight-bearing position. Shoes made from lasts which are flat in front exert pressure on the inner side of the front foot, forcing it down to a lower level. To reach this lower level, the front of the foot is turned out, twisting at the mid-ankle cross joint, and the inner arch is pulled in and down. A knock-ankled, splay-footed, and weaker static position is unconsciously taken, which, in turn, under fostering conditions may produce a crippling plano valgus, i. e., a painful and stiffened flatfoot.

The American last is often not only too flattened in front, i. e., back of the ball of the foot, but also is even concaved down. In shoes made from such lasts, free action of the toes and the toe grip — important in heavy weight-bearing or in fast walking — are seriously hampered and, indeed, in anything but an over-loose shoe, are made practically impossible. This is not obviated by making the sole of the shoe wide, because the leather of the shoe stitched firmly to the stiff sole acts as a band, tying the toes down flat. Flattening the last in front also produces a shoe which presses upon the distal ends of the metatarsals. When the foot slips forward in the shoe in walking, this produces a strain upon the middle of the front of the foot which it was never shaped to bear, humps the middle of

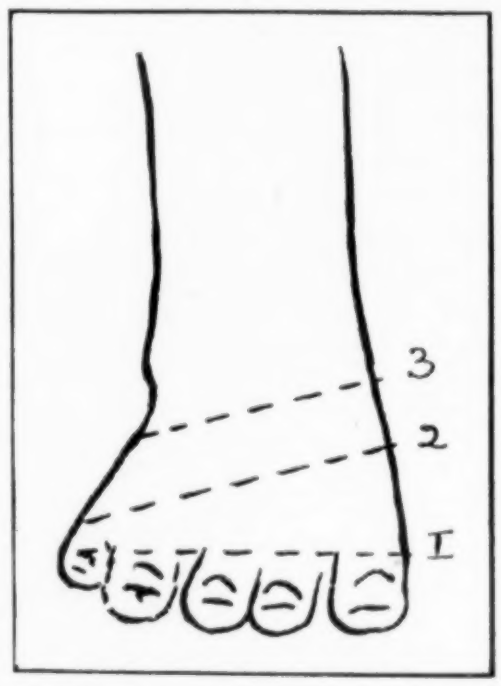

FIG. 2. — Diagram of foot in strong position, showing the inner edge of the foot higher than the outer.

the foot up and presses the heads of the metatarsals down. This causes a strain upon the plantar muscles and causes contraction of the toes, giving rise in extreme cases to the so-called claw foot.

These defects in the shape of lasts, although important, have received much less attention than they deserve, and it is for this reason that they are referred to in this article in preference to other defects already noted by medical writers. A disregard of the above-mentioned facts impaired the usefulness of the army shoe in the last war. Owing to the fact that the army shoes were too greatly flattened at the front to be serviceable, it was necessary to supply unduly long and loose shoes. Where this was not done foot strain was apt to follow. A Red Cross nurse who returned from service at the front reported that the soldiers in her hospital complained more of their feet than of their wounds.

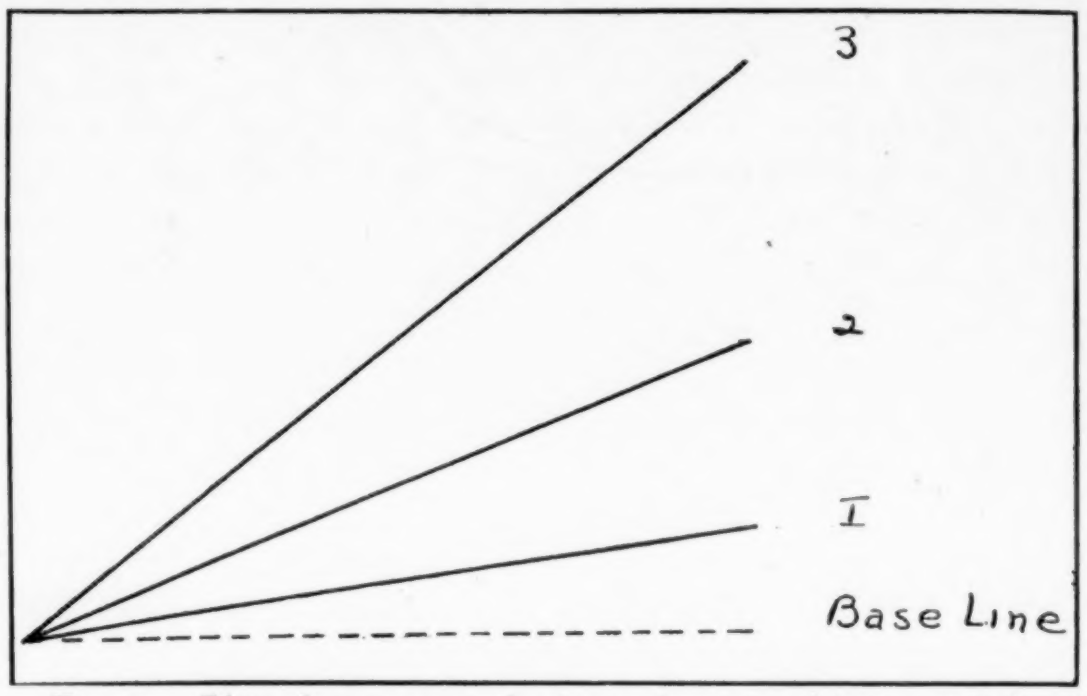

FIG. 3. — Lines drawn across the front of a normal foot, not injured by shoes, placed in a strong weight-bearing position.
1. Across the line of the toes.
2. One inch back across the line of the toes.
3. Two inches back across the line of the toes.

A reformer in the matter of footwear is at once confronted by the statement that shoes are made to sell and that as long as improperly shaped shoes are the only ones salable, manufacturers can only make such shoes. The argument would be forcible if it were true. At present the working public is, so far as its footwear is concerned, at the mercy of manufacturers of shoe lasts. There is a definite need of shapely, non-injurious shoes for working people, and the exercise of properly directed business energy in this direction would find ample financial return. There is no doubt that to a large class of individuals who need foot strength but little, footwear is a matter of costume, and the style of a shoe is what sells it. This desire for appearance need not be neglected, but anyone familiar with former shoe fashions can satisfy himself that styles can be manufactured which would become fashionable and at the same time be less injurious than those now forced upon the American public.

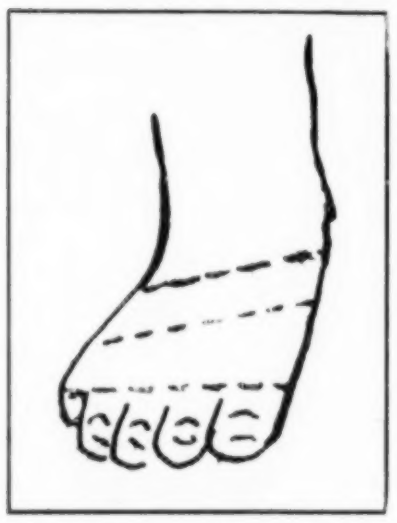

FIG. 4. — Weak weight-bearing position.

The prevention of the widespread foot disability and static weakness in our communities caused by shoes, is not as difficult a task as might at first be supposed. It is first necessary that the shoe-purchasing community should be made aware of the fact that ill-designed footwear cripples the feet. Individuals must be taught to distinguish between the footwear which can be safely worn in leisure hours and the footwear which is needed when they are at work and must economize their foot strength. That this fact is recognized in the army is shown in the difference between army and civilian shoes. Tennis, gymnasium, baseball, and nurses' shoes are all products of a need for suitable work shoes. At one time the shoe market was flooded with cramping styles of infants' and children's shoes. A few energetic manufacturers had the good sense to turn out more sensible styles with the advertising caption, "Every toe a helper." This resulted in the gradual improvement of children's footwear.

There is also among shoe manufacturers an earnest effort to produce so-called hygienic and orthopedic shoes. Further attempts in this direction, guided by somewhat more accurate anatomical and physiological knowledge of the needs of the foot, could easily produce shoes which would be much less injurious and at the same time not unsightly. The nurse's shoe can easily be made as well adapted to its service as the baseball or football player's shoe, and yet retain its saleable quality.

There is no reason why the large employers of labor should not pay as much attention to the subject of proper foot-

wear as is done by the quartermaster's department of an army, and there is little doubt that shoe manufacturers would readily fill any orders which might be presented in this way. If working shoes were made in sufficiently presentable styles, they would undoubtedly be gradually adopted, especially if they were sensibly recommended by industrial physicians, many of whom are employed in an advisory capacity in industries demanding foot strength of their employees. Advisory physicians should not, however, content themselves with advocating sensible shoes and preventive measures for checking the development of foot disabilities. They should inform themselves as to the best practical methods of relieving existing foot weakness and of instructing working people how to strengthen or how properly to utilize their remaining foot strength. It does not, however, fall within the scope of this article to describe the surgical methods which specialists can make use of in the correction of various severe static foot distortions or grave shoe-caused deformities. The advisory surgeon may well inform himself of these and can easily acquire familiarity with such surgical procedure. A little experience will enable him to judge the various grades of the more common static disabilities, and to apply suitable means of relief.

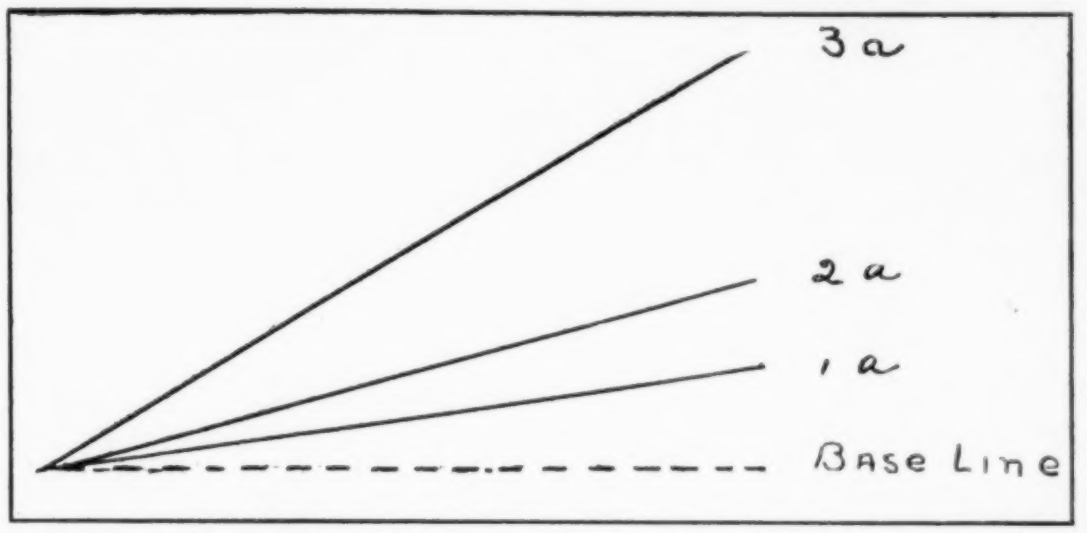

FIG. 5. — Lines drawn across the front of the foot in a weak weight-bearing position.

1a. Across the toes.
2a. One inch back of the line of the toes.
3a. Two inches back of the line of the toes.

This figure indicates the amount of the dropping of the arch and the lowering of the inner side of the foot when the foot is held in a weak weight-bearing position.

A physician can form his judgment as to foot defects, not only by watching the gait of the individual examined and the standing and sitting positions of the foot in its habitual relation to the line of the whole limb, but also by observing the footprint of an individual whose bare foot has been dusted with talcum powder and who is then made to walk about on a wood or a linoleum floor. A plaster of Paris cast is unnecessary and may be misleading since it gives only the contour of the foot at rest and not in action. The flexibility of the joints of the feet should be examined and any stiffness noted in the plantar flexion at the metatarsal joints of the toes. It should be noted also whether the ball of the great toe does its share of weight-bearing as indicated by the callosities of the sole, and whether the great toe joint has not been forced up to a higher level than the corresponding joints of the middle toes, causing a flattening of the front cross arch of the foot. The spreading power of the front of the foot should also be examined when weight falls upon it, and when the heel is raised as in walking up and down stairs. The side flexibility at the cross joint of the ankle (the astragalo-scaphoid and calcaneo-cuboid articulation) should be determined, especially to the inner side, as any abnormal stiffness in this direction marks a tendency toward the development of static flatfoot (plano valgus). This can be detected by holding the leg firmly near the ankle with one hand, while the other hand grasps the front of the foot and moves it sideways. A loose heel bone (os calcis), resulting from undue weakening of the calcaneo-astragaloid ligament, can be determined by an attempt at sidewise movement of the heel bone.

When a patient is standing on one foot, the mid-line of the weight-bearing foot should be noted in its relation to the mid-line of the whole limb. This line does not normally fall to the inner side of the weight-bearing foot; there should not be an undue prominence of the ankle bone to the inner side; nor should the heel bone of the foot as seen from behind appear to slide to the outer side of the mid-line of the leg. The side contour of the foot should be noted particularly. In flatfoot there may be also a prominence of the bone in the middle of the foot with the toes drawn up in a claw-like position. Looking down upon the foot the toes should not be crowded, but should be flat and straight,

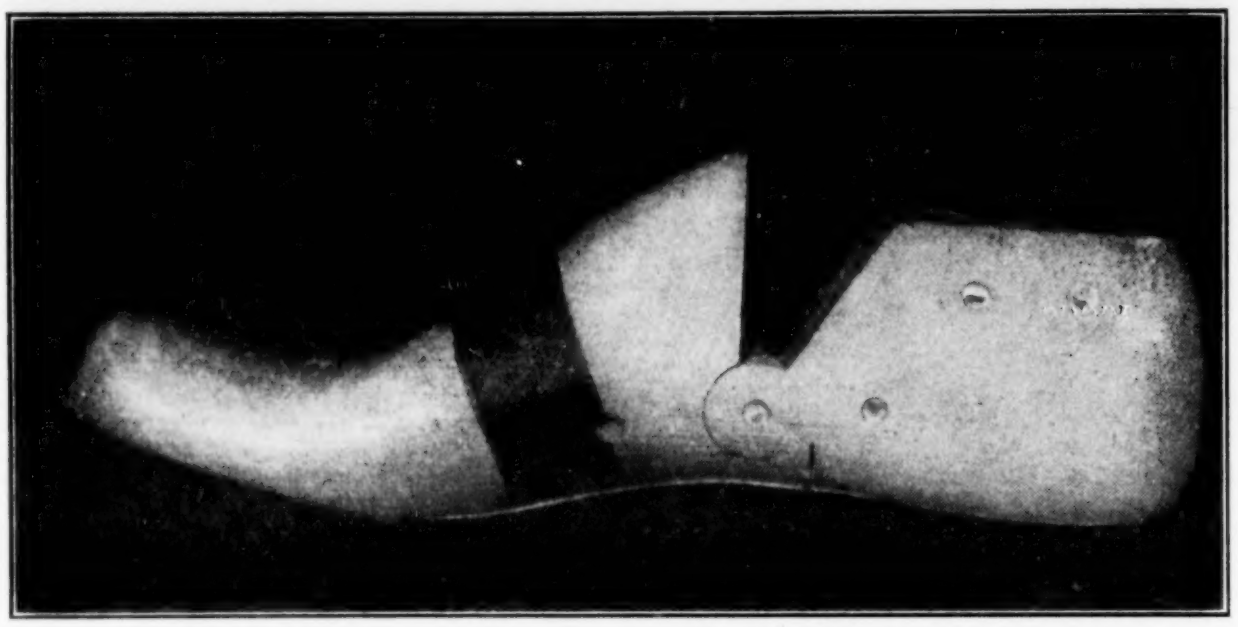

FIG. 6. — Photograph of last of improved army shoe, showing undue flattening of the last on the front of the foot.

following the mid-line of the foot. An exception to this may be made of the little toe which is always curled in shoe-wearing people — a slight deformity. There should not be a depression at the base of the middle toes. The front of the foot should be well rounded up, but the inner side, from the great toe up to the ankle, should be much higher than the outer side. The sole of the foot should be well muscled. A thin and apparently high-arched foot is often an indication of plantar muscles weakened by improper shoes or prolonged wearing of arch supporters.

Stiffness of the joint at the ball of the great toe, projections, and redness in this region — the result of shoe friction or of pressure of shoes too flat on the inner side — are of importance, as well as the common outward deviation of the great toe. This latter, so usual in individuals who wear pointed-toe shoes, is of less importance as a disability for standing or for slow walking than for persons needing active front foot walking. This is also true of other toe distortions, unless heavy lifting or long standing is demanded.

Much can be learned, from an examination of the shape and sole-wear of worn shoes, concerning the strain of the foot upon ill-adapted footwear, but one must remember that there is an individuality in gait not easily recognized by the individual himself or by the observer, and that people often vary in the work they put upon the different feet, being right or left-footed. X-ray pictures of both the bare and the shod foot are serviceable in determining how the foot lies in the shoe.

The examiner will be able readily to make the observations necessary for an estimate of the static foot ability of those examined. It is, moreover, of importance that such an estimate should be considered in connection with the subjective symptoms mentioned by the patient, i. e., pain and fatigue. A distorted foot may give but little pain and an apparently well-shaped foot may give much discomfort if improperly shod or overworked. If this is borne in mind, mistakes in judgment may be avoided. The question is not one of degree of deviation from the normal so much as it is whether or not the individual is able to stand up under his load. A number of instances have been observed in the recent draft examinations, where splay-foot track walkers and long-distance runners were rejected by conscientious examiners, though more capable of tramping than many accepted men. In many other instances, weak-footed soldiers were cured when properly shod.

After rejecting or assigning to sitting work those manifestly unable to endure long hours of foot strain, we have left a large class of people whose feet can be brought into excellent working condition if properly nursed. The treatment of foot

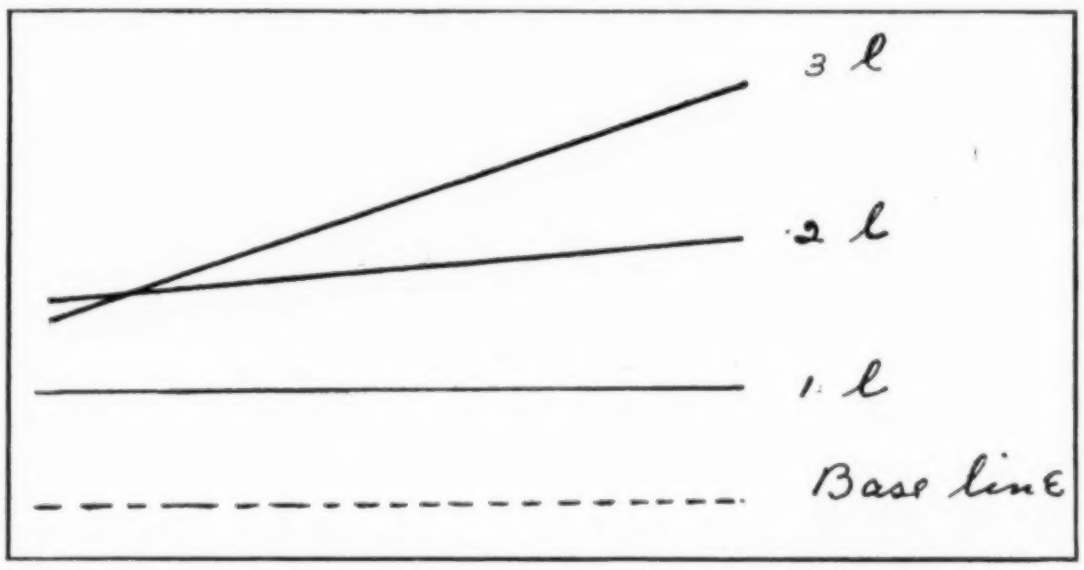

FIG. 7. — Lines drawn across the army last, showing flattening at the toe line and insufficient height on the inner side.
1l. Across the line of the toes.
2l. Just behind the line of the toes.
3l. Two inches back of the line of the toes.
This diagram indicates that the army last is not sufficiently high on the inner side.

strain differs in principle in no way from the treatment of strain elsewhere. There should be avoidance of the exciting causes of strain, proper rest and massage or other measures to stimulate impaired circulation, and, finally, use of the foot should be permitted to a gradually increasing degree.

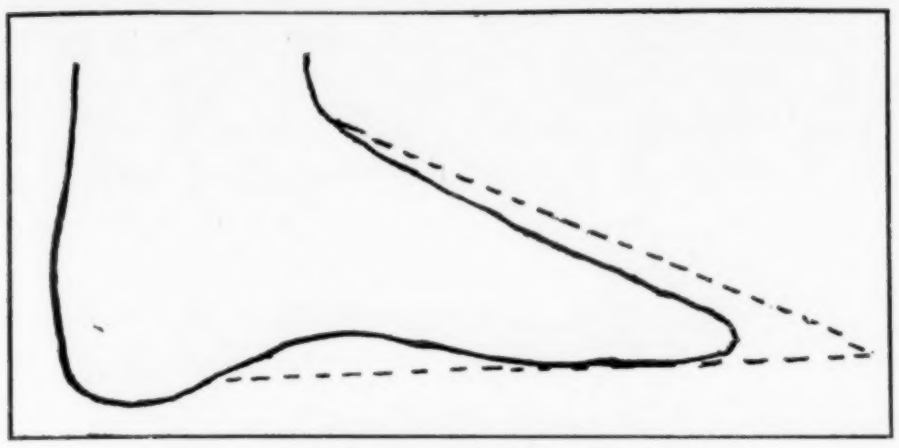

FIG. 8. — Diagram of side view of foot.

Adhesive plaster strapping and bandaging, needed in the acuter stages of strains, are not suited to the chronic stages which demand measures to increase the circulation and to strengthen weakened tissue, and then gradually increasing use. Massage and graded exercises are of service, but it is of prime importance that the individual should recover the natural position in which the body weight falls properly upon the foot and not in such a way as to bring undue strain upon overworked ligaments. In a large number of cases, the recovery of the proper position is possible by barefoot walking on a sand beach or on turf, or by the free use of moccasins in leisure hours. The feet of every individual should be freed from shoe constriction and given, if only for a brief time each day, emancipated use. Even the constriction of the stocking, certainly that of the pointed slipper or shoe, limits the proper exercise of the plantar digital muscles and simple daily exercises, such as rolling heavy dumb-bells with the feet, attempting to grasp a towel with the feet, balancing the body on one foot upon the yielding surface of a mattress or cushion, or similar exercises, systematically and daily used, are effective in restoring foot power. Where stiffness of the joints, limiting the flexion and side movements of the front of the foot, is present, manipulations are needed to give proper static suppleness to the weight-bearing foot. Cases of fixed distortion, where more than ordinary measures are required, need not be condemned as incurable, but such cases demand the care of a specialist.

Whatever treatment is needed, it is manifest that the foot, during working hours, should not be boxed in unyielding shoes or in shoes which make difficult or impossible the proper weight-bearing position of the foot or the free use of muscles needed for correct standing and walking. Improper shoeing causes the foot to suffer and diminishes the static power of the individual.

Reliance is often placed upon arch supporters to help relieve the strain of the superimposed body weight. The custom-made stiffened insoles sold by shoe dealers for this purpose are useless. When an X-ray picture is made of a shod foot with such a support under the sole, the plate will be seen not to be under the part of the foot which needs the maximum splinting. What is needed is not a support to hold up the arch of the foot and thus to prevent its flattening, but something which holds the foot from falling under the body weight too far to the inside of the mid-line. Plates constructed to do this effectively are heavy. Moreover, they do not serve their purpose except in the standing position with the weight falling directly upon them, and are not of use in other phases of gait. More than this, if continuously used they cause by their pressure, as do splints applied to the limb, weakening of the muscles, and are therefore eventually injurious.

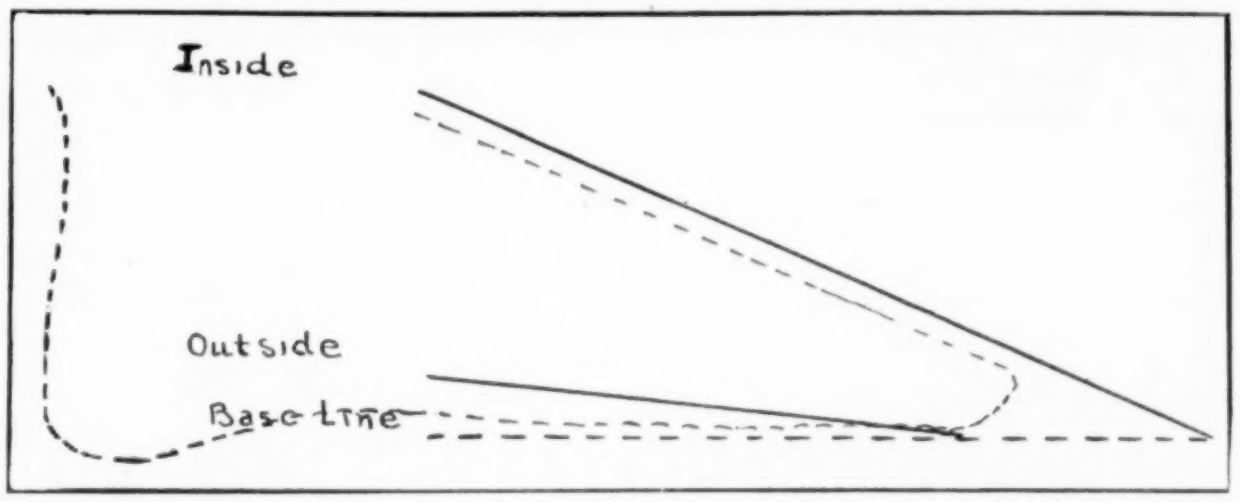

FIG. 9. — Diagram of lines laid over the outer and the inner side of the bones of the foot. Side view showing how much the inner edge is higher than the outer edge. Unless the shoe is shaped to meet this, it tends to throw the foot wrong.

Shoes shaped with the purpose of correcting deformed feet on so-called orthopedic lasts are necessarily ineffective if they are intended to force the foot into a normal position. In short, working people whose

foot muscles are so weakened that plates and special shoes are needed, require individual treatment. A support is a crutch and a crutch means a cripple. To put a supporting plate inside a muscle-cramping shoe is as irrational as to continue a poison while applying an antidote. Many individuals who have worn close-fitting muscle-binding shoes cannot suddenly change to muscle-developing shoes. The change must be gradual, with slowly increasing use of non-constricting shoes. The eventual use, however, of a suitable non-foot-binding shoe is necessary for foot strength and health.

There are four important facts, which are often overlooked, to be remembered in considering the working capacity of feet:

1. The spreading power of the toes and front of the foot.
2. The strength of the toe clutch upon the weight-bearing surface.
3. The greater height of the inner side of the foot, as compared to the outer side, from the ball of the great toe upward to the ankle, while the foot is in the habitual non-weight-bearing position.
4. The degree of the mid-ankle motion to the inner side.

Shoes made for and worn during working hours without regard to these facts hamper the functions of the foot and impair its normal service. It is evident that more is required than the statement of surgeons as to the need of improved lasts. The purchasing and manufacturing public must first be convinced of the desirability and possibility of improvement in the style of shoes, and then they must be informed as to ways in which this improvement can be accomplished.

A muscularly inferior man may walk to his work on a sidewalk without discomfort or knowledge that any of the muscles of his feet are checked in possible action. If, however, this same individual is forced to carry a heavy load over an uneven surface, he will not be able to stand up to his work as well as a stronger-footed person. If he wears, as do so many working people, footwear which checks toe spread and toe grip and throws his feet out of line, he becomes physically inferior to his more sensibly shod competitors. Much activity is possible with little use of the toes. The Chinese bind the feet of their women to limit their activities and yet the crippled women are quite active on their deformed feet. North American Indians cut off the toes of their captives that they might be

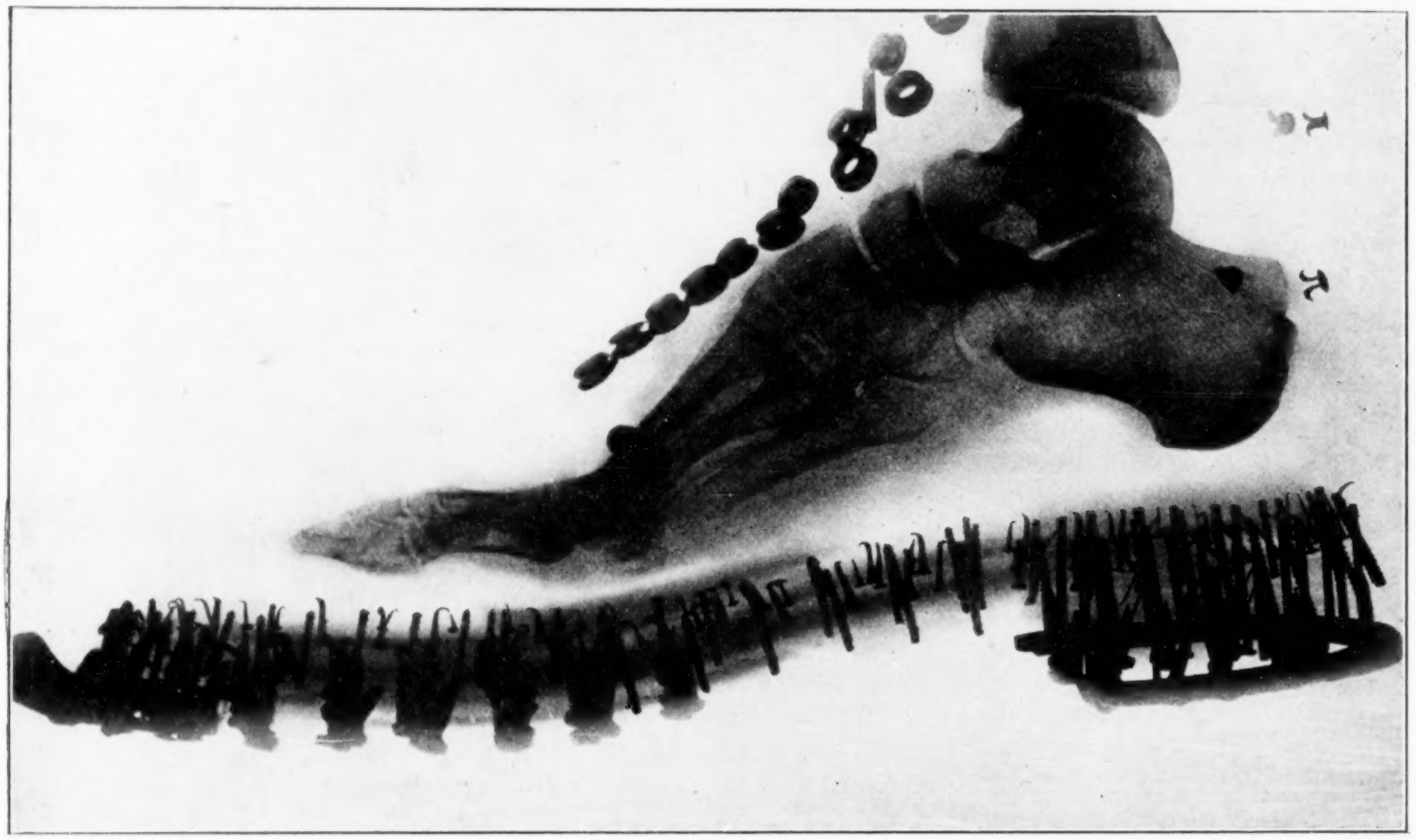

FIG. 10. — X-ray picture of the foot in the Pershing army shoe, indicating the effect of a shoe made on a last flat across the line of the toe joints, and the necessity of an unduly large shoe to enable the foot to slip into a shoe made from a last too flat on the inside.

able to do standing work but could not run away. The ordinary commercial American shoe checks the spread and play of the toes and front foot, and hampers the force and strength of the toe grip and push.

It has been a matter of national pride that Americans have achieved distinction in international track athletics, but the events in which they have excelled have required limb strength more than foot strength. Indeed, the records of Americans in Olympic and international Marathon runs requiring toe clutch and foot endurance for a long distance have been by no means as good as in other sports. In the recent games at the new Pershing Stadium in France the Americans were easily winners, but they were beaten in the Marathon and cross country run by two Frenchmen. The French claimed that the Americans had dash, but lacked endurance. Perhaps the lack of endurance is due to the use of faulty shoes.

Both the Turkish porter who can carry a piano on his back and the Japanese rickshaw man would outclass the American in foot strength. It may be argued that the American is not a hewer of wood and a drawer of water; that with machinery he can supplement the heavy work of serfs and peasants. This argument, however, can be disregarded inasmuch as heavy labor will always be needed. Certainly there is no reason why the American should be content to remain in any respect muscularly inferior when this can be, in part at least, prevented by removing an important cause of his foot weakness — i. e., ill-shaped footwear for working hours.

There is no doubt that the shoe last can be improved. It ought to be possible to bring the buying public, the dealers and the manufacturers to a common understanding. The American of fifty years ago was sensibly and well shod. The American of today is not wanting in intelligence. He does not want "freak" shoes, but how can his wife or the working woman easily purchase anything else? A condition of affairs in which 177.45 per 1000 of our recruits are rejected as incapable of heavy work, when a normal foot is hard to find in our city population, when even the shoes of our soldiers are faultily shaped — such a state of affairs is not one in which to rest content. We are waiting for a manufacturing Moses to lead us out of the land of foot thralldom, for a Saul among the retailers who will free the public from shoe bondage, or for a liberating Garrison who will arouse the public to demand emancipation from the tortured servitude of mistreated feet.

REPORT ON CERTAIN ORGANS IN A CASE OF FATAL POISONING BY ARSENIURETTED HYDROGEN GAS*

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[As there are very few (if any) accounts published of the microscopical appearances of the principal organs — the liver and kidneys — affected in poisoning by arseniuretted hydrogen gas, the following account of one such typical case by Professor Sheridan Delépine has interest. His report shows how different is the condition of the liver found from that of phosphorus poisoning or from that accompanying toxic jaundice, the result of poisoning from nitro-derivatives of benzene and its homologues.

The process upon which the deceased man, A. R., aged 45, was engaged was one for the extraction of metals from zinc chloride. The zinc, containing impurities, was dissolved in hydrochloric acid, this being added until the solution was neutralized. The mixture was then filtered in presses, the resulting liquor being subjected to the action of massive zinc by passing the liquor over bars of zinc. The resulting liquor was next treated with zinc dust to cause precipitation of certain of the metals, the zinc dust being first mixed with water to facilitate the action. The process was carried out in rather a confined shed in open vats.

A. R. was working on this plant and tipping the zinc dust into the liquor, when a more violent action than usual occurred with the result that the liquor "boiled over." He was at work from 2 P.M. till 10 P.M. On his way home he felt sick and vomited, could not eat any supper and during the night was sick and had pain in the stomach. He went to the doctor's surgery the next morning, complaining of gastro-intestinal diarrhea. The case was regarded as one of gastro-intestinal disturbance due to food, as such cases had been very common in the district for months. Two days later he was seen to be distinctly jaundiced but with general symptoms somewhat improved. He said he thought the "zinc" process in which he had been engaged had affected him, and, in the opinion of the chemist, arseniuretted hydrogen gas might have been evolved. A. R. was removed to the Victoria Infirmary, Manchester. He seemed to improve in the Infirmary, sickness, diarrhea, and pain ceasing, and he took nourishment freely. As no urine, however, had been passed in the Infirmary, a catheter was used, and 2 ounces of a brownish fluid drawn off showing that hemoglobinuria was present. Seven days after he left off work there was total suppression. He became gradually weaker, and vomited again; he passed into a drowsy condition and died on the eighth day. — *T. M. Legge.*]

ON June 21, 1917, I received from Dr. J. C. Bridge the liver, spleen, right kidney, stomach, part of the pancreas, part of the left ventricle of the heart, and some of the blood from the right auricle of A. R., *aet.* 45, who had been working in connection with a process of extraction of cadmium, lead and copper from zinc chloride, and whose death was suspected to have been due to the inhalation of arseniuretted hydrogen. The man died on the eighth day after exposure. A post-mortem examination was made on June 21, about forty-eight hours after death.

General Post-Mortem Appearances

From the post-mortem notes communicated to me by Dr. Bridge, the following particulars may be quoted briefly as having a bearing upon the investigation which I carried out subsequently in the laboratory.

The *heart* was soft and its walls appeared to be slightly fatty.

The *lungs* showed considerable hypostatic congestion.

The *liver* surface was smooth; the cut surface was pale and showed signs of a fatty change with possible fibrosis.

The *right kidney* weighed 8 ounces, was enlarged and dark on its external surface; the cut surface was pale and apparently fatty.

The *left kidney* weighed 9 ounces and had a similar appearance.

The *spleen* weighed 4½ ounces and appeared darker than normal.

The *pancreas* weighed 4½ ounces and was apparently normal.

The *brain* appeared normal.

The *bladder* contained about 1 ounce of decomposed dark urine. (There had been suppression of urine during the last two or three days.) †

The following additional notes were taken by me when I received the organs previously enumerated:

Liver. — Weight, 1757 gm. (3 lb., 14 oz.). Large, not very soft; capsule smooth; parenchyma generally pale, as if in a state of cloudy swelling or early fatty degeneration. Superficial part of the upper region of the right lobe, purplish in color; other parts of the parenchyma slightly bile stained; central parts of the organ and more particularly the tissues adjacent to the large vessels purplish-black in color as if stained by altered blood pigment. Gall bladder moderately filled with dark green bile.

* Received for publication July 30, 1919.

† Between November 14, 1918 and February 3, 1919, I examined the urine of thirteen men engaged at important dye works in carrying out certain operations requiring the use of hydrochloric acid and zinc dust. I found arsenic in the urine of four of these men. The amount of arsenic was very slight in one case but material in the three other men, who were suffering at the time from albuminuria and methemoglobinuria. In two of these cases the urine contained also hyaline and granular tube casts and some precipitated pigment. On re-examination of the urine of these two cases I found that, after two to four weeks' treatment, the albumen and methemoglobin had disappeared and that only immaterial traces of arsenic could be detected. — *S. D.*

I handed over to Mr. Heap a portion of the organ for the estimation of arsenic by the hydrochloric-copper (Reinsch-Delépine) method and he found 0.01 mg. of

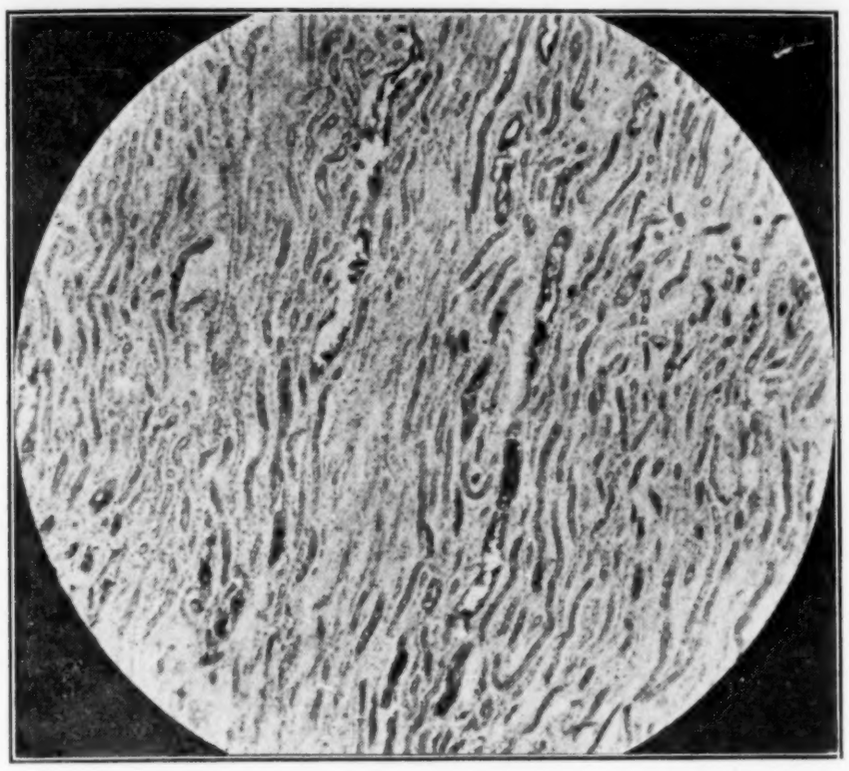

FIG. 1. — *Kidney.* Longitudinal section through the boundary zone of a malpighian pyramid, showing the accumulation of pigment in the straight tubes, and the slightness of the changes in the loops of Henle and their ascending and descending limbs. × *40.*

arsenious acid in 200 gm. of liver, which makes 0.0000878 gm. for the whole organ.

Spleen. — (4 oz.) Small, shrunken looking, but normal in shape, capsule wrinkled, pulp moderately firm, more brown than usual.

Right kidney. — (8 oz.) Considerably enlarged; length, 5 inches; width of upper part, $2\frac{3}{4}$ inches. More rounded than normal, otherwise normal in shape. Surface smooth, capsule peels off readily. Small white infarct at one place. Exposed surface looks granular, owing to the whole surface being punctated by small dark brown spots, contrasting with the paler intervening cortical substance. Thickness of cortex, $\frac{1}{4}$ inch; of medulla, $\frac{1}{2}$ inch. There are in the cortex and medulla a number of spots and of straight sinuous dark brown lines, conspicuous owing to their size and to their dark brown colour which contrasts with the paler unusual brownish colour of the glandular tissue. These produce the impression that the vessels are distended with dark blood. The boundary layer of the medulla is very dark owing to the large number of these dark lines.

Pancreas. — (The only part of the organ available for examination is the tail.) Tissue firm, otherwise normal. There are several lymphatic glands conspicuous on account of their dark brown colour (possibly spleniculi) along the upper border of the pancreas.

Stomach. — Appears normal in size and shape. Mucous membrane thick and soft, mammillated at places. Some parts show some brown discolouration, possibly the result of congestion, but no characteristic lesion is obvious.

Duodenum. — The small part of the duodenum attached to the stomach is deeply congested.

Heart. — The small piece of the ventricular wall available for examination is pale, but shows no clear naked-eye evidence of fatty degeneration.

(Various parts of the organs were hardened respectively in formal, methyl-alcohol, and 2 per cent. bichromate of potash solution for the purpose of microscopical examination.)

MICROSCOPICAL EXAMINATION OF THE ORGANS

Heart. — Longitudinal section of one of the papillary muscles of the left ventricle.

There is no obvious alteration of the endocardium. The muscular fibres are unequally altered, and show an abnormal degree of segmentation. In many places

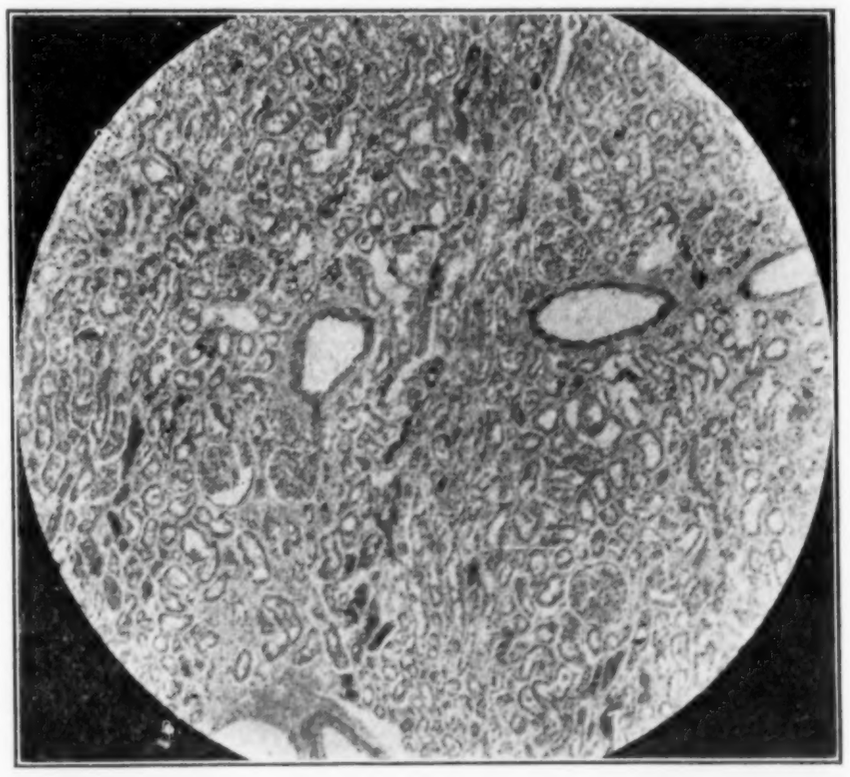

FIG. 2. — *Kidney.* Section through the deeper parts of the cortex adjacent to the boundary zone, showing the accumulation of pigment in the straight tubes and the increased size of the lumen of the convoluted tubes, due to the degeneration of the central part of the secreting cells forming their lining. × *40.*

the striation is not materially altered, in other places the transverse striation is indistinct and the longitudinal exaggerated. Some of the fibres are granular, but very

few of the granules give, with osmic acid and Sudan III, a clear reaction of fat. The brown pigment granules at the poles of the nuclei are very distinct, but there is no exceptional pigmentation of the fibres. Most of the granules give a slight doubtful fat reaction with osmic acid and Sudan III.

The nuclei of many of the myocardial cells stain badly, and some not at all with hematein. This is particularly noticeable where the myoplasm is granular or its striation altered.

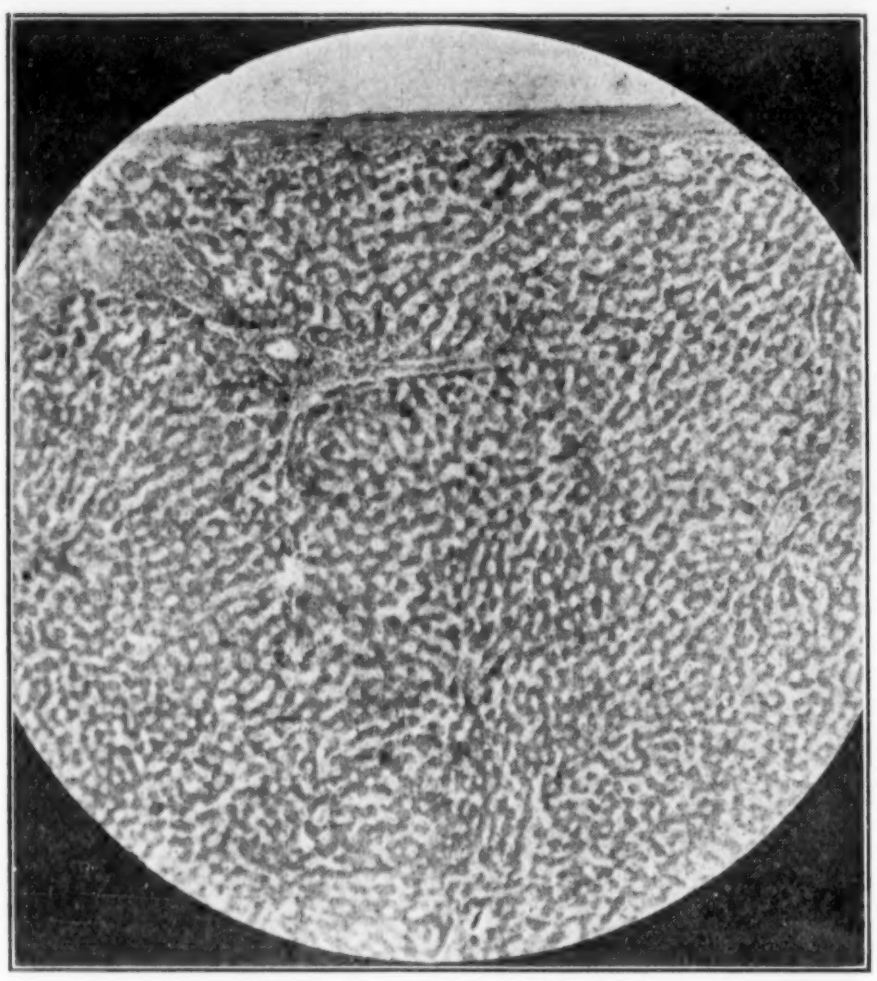

FIG. 3. — *Liver.* Section perpendicular to the surface of the organ, showing the absence of cirrhotic lesions and of general fatty lesions. The shrunken state of the liver cells and the wide spaces occupied by the intralobular capillaries and perithelial tissue are well shown. × 40.

Liver. — Section perpendicular to the upper surface of the right lobe.

There is no increase of connective tissue round the portal vessels, and the liver appears to be exceptionally free from cirrhotic changes. The larger portal and hepatic vessels are generally empty. A few of them contain finely granular matter or hyaline clots, but no distinct blood corpuscles.

The blood capillaries are very much distended and generally contain swollen, decolourized, red blood corpuscles among which are a few white corpuscles, mostly small, lymphocyte-like. In several places the blood corpuscles are replaced by finely granular matter and pigment granules of various sizes. The walls of the capillaries are unusually distinct. The nuclei of the endothelial cells are small, but stain well; the space between the walls of the capillaries and the liver cells, which is indistinct in the normal liver, is very distinct in places. (This is probably the result partly of oedema and partly of the shrinking of the liver cells.)

The shrinking of the liver cells renders the arrangement of the columns which they form exceptionally distinct. Many of the hepatic cells are vacuolated. This is particularly marked in the portal zones of the lobules. The vacuoles are not generally large, but in some of the cells they are so numerous as to give the cells a spongy appearance. In some places the vacuoles are seen to communicate freely with intralobular bile canaliculi. In these cells the nuclei are indistinct or stain very faintly with ordinary nuclear stains. The contents of the vacuoles do not stain with osmic acid or Sudan III, except in some places, where a few of the smaller vacuoles (and globules at the periphery of some of the larger vacuoles) also give a fat reaction, but this is exceptional. Many of the cells are pigmented. The reddish-brown pigment is partly in the form of fine granules, such as are found in connection with cyanotic atrophy of the liver, and partly diffused through the cells. Some of the pigment granules give an ill-defined reaction of fat with osmic acid. Most of the pigmented cells are situated in the hepatic and portal zones of the lobules, but some of them are found here and there in the intermediate zone also. None of the granules give the reaction of free iron with ferrocyanide of potassium.

The nuclei of the hepatic cells are generally capable of being stained with hematein, but they stain very unequally. Their size is also subject to great variations.

A section through the left edge of the left lobe of the liver showed changes identical with those observed in the right lobe. These changes may be summed up by saying that the liver was in a state of dropsical degeneration, with considerable atrophy, pigmentation, some necrosis, and very slight fatty degeneration of the secreting epithelium.

Kidney (right). — Section perpendicular to the surface of the upper end.

The capsule is thin and apparently normal and there is no increase in the subjacent connective tissue. Deeper in the cortex there are a few small patches where

some increase of connective tissue is noticeable, and where some malpighian bodies are in a state of hyaline degeneration. The surface of the capsule is uneven owing to a large number of the subcapsular convoluted tubules being much swollen.

All the capillary and interlobular vessels are empty and some of them are contracted. The larger vessels in the sinus are also empty, but are otherwise normal. The glomerular vascular tufts are large and generally fill entirely their capsules but in some cases they are shrunken, and the space between them and the glomerular capsules is filled up with granular material. The epithelial lining of the glomerular capsules is, in many cases, thicker than normal.

The epithelium of the convoluted tubules seems in many places to be replaced by a low cubical epithelium and the lumen of the tubes to be of considerable size. This appears to be due to the breaking up in each of the cells of the half of the cell turned toward the lumen. In many convoluted tubes this central part of the secreting cells is much vacuolated, forming a spongy mass coalescing with the central parts of adjacent cells similarly affected. This spongy mass entirely fills the central part of the tubules. In other places all that remains of this degenerated part of the cells are a few irregular debris, or some finely granular material. The spiral tubes are in the same state. The limbs of the loops of Henle are less altered.

In a few of the convoluted tubes there are pigment granules of various sizes staining faintly, like red blood corpuscles with orange. Many of the junctional tubules contain numerous pigment granules, giving this reaction more clearly. The epithelium of the cortical straight tubes is much less altered than the secreting epithelium of the convoluted tubes, but the lumen is generally filled, often to distention, with round granules of yellowish-brown pigment of which some have nearly the size of red blood corpuscles, but the greater number are much smaller. All these are highly refractive and somewhat oily looking: they are brightly stained with orange, the colour being not unlike that taken by red blood corpuscles, but deeper and darker. With osmic acid and Sudan III these granules do not give the reaction of fat, but among them there are few globules which give a fat reaction A few fatty granules are also present in some of the degenerated epithelium of the convoluted tubes, but this is exceptional. Some of the granules in the lumen of a few of the convoluted tubes give a clear reaction of fat. In the larger medullary straight tubes the pigment granules are present in such numbers as to cause distension of the tubes; they also show a marked tendency to coalescence, and in the larger excretory ducts near the apex of the pyramids the epithelium is partly covered by a thick continuous layer of pigment caused by the coalescence of the granules. In a few of these tubules cast-like masses are observed.

The nuclei of the cells of nearly all of the excretory tubes stain fairly well and evenly with nuclear stains. The nuclei of the secretory cells stain more unequally, but more completely than could be expected in cells which seem to be in a state of dropsical degeneration or incipient necrosis. It is possible that necrosis of the renal epithelium is more advanced than the usual histological reactions would indicate, and that the nature of the poison has altered the usual reactions of the nucleoplasm.

None of the granules give the reaction of free iron with ferrocyanide of potassium.

Spleen. — The sections of the spleen are unsatisfactory. The malpighian bodies show no obvious change. The pulp shows the following alterations: No blood is visible in the sinuses, which are much reduced in size and contain a small amount of finely granular matter. The cells are also finely granular, but the nuclei stain well. There is no abnormal accumulation of pigment either between or within the cells.

THE HEALTH HAZARDS AND MORTALITY STATISTICS OF SOFT COAL MINING IN ILLINOIS AND OHIO

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BY means of direct field investigations in which forty-three mines in Ohio and fifty-six mines in Illinois were visited, including their surrounding towns, and by means of questionnaires and conferences with officials and mining physicians, the subject of the health and hygiene of coal miners was investigated in an automobile tour during the summer of 1918. The general results of this survey have been or will be published by the Illinois and Ohio State Boards of Health, by the Health Insurance Commissions of these two states — all of which agencies were concerned in the survey — and by the author in a paper appearing in recent issues of *Modern Medicine* (June and July, 1919). The purpose of the present article is to present some of the technical findings regarding the health hazards of soft coal mining, and to give the results of the study of the mortality statistics in this occupation — features of the investigation which have not before been published in detail.

The following brief summary reviews the results of the survey as already published. In both Illinois and Ohio soft coal only is mined. The industry in these states is steadily increasing; it employs approximately 50,000 workmen in Ohio and 90,000 in Illinois. The quantity of coal in sight in both states is sufficient to last for centuries. Healthful working conditions in Ohio mines are not as good as the average of most industries in Ohio. On the other hand, conditions are good in Illinois mines. Ohio mines are shallow and of a damp, muddy type in contrast to Illinois mines which are deep and dry. Forced ventilation, required in all mines, is quite good, but the air of Ohio mines is much vitiated by the practice of shooting down coal with powder during working hours. This is not allowed in Illinois. In both states there is a shortage in the personnel of state-paid mine inspectors, and particularly in Ohio; also their salaries of $150 per month are unquestionably too low for expert men in responsible positions.

By law, Illinois mines are equipped with wash houses in which the men may bathe following work. Upwards of 90 per cent. of the men use them. Such conveniences are rare in Ohio mines. A glaring omission at practically all mines is the absence of latrines for workers on the the surface, so that the fly menace and ground pollution is bad in mining towns. Equally as bad is the drinking water supply, both for mines and towns.

The eight-hour day prevails. There was practically no overtime even during the war stress — a day shift only is maintained.

All miners are unionized. Foreigners principally Eastern Europeans and Italians predominate. But slightly over 3 per cent. of the workers surpass sixty years of age. Wages are good, but in normal times many mines are idle for weeks and months each year because of the lack of demand for coal (hence the miners' demand for a six-hour day). Disastrous strikes have also caused great suffering.

Housing conditions, and hurtful forms of recreation, especially alcoholism, undoubtedly cause the major amount of sickness. The mine itself is not an unhealthful place in which to work. Lack of interest in these districts on the part of the population of the rest of the state is a potent reason for low standards of hygiene in mining districts.

Rheumatism, " asthma," and alcoholism constitute the chief afflictions, and all are believed to be above the average. Tuberculosis and pneumonia have about the same prevalence as elsewhere. Venereal diseases are conspicuously less. Several diseases supposedly of industrial character among miners, such as hook-worm, nystagmus, and lockjaw, are practically nonexistent.

Miners have devised many schemes of sickness insurance and death insurance. None are adequate; most have a struggling existence. About 50 per cent. of native American miners carry some form of sickness insurance in locals or in fraternal societies. About 90 per cent. of foreign workers carry such insurance in religious societies. Establishment funds do not

exist. In Illinois the state miners' organization pays a death benefit of $250. In both states practically all locals also pay death benefits ranging from $25 to $200 and usually including death in the miner's family. A common procedure for aid in case of sickness is "to pass the hat." Miners often belong to several benefit societies and may derive over-insurance therefrom. The usual industrial insurance by private companies, providing a small burial fund for children, is extensive.

Practically all community medical facilities are seriously inadequate. First-aid alone is generally beyond criticism, this due to the insistence of state mine bureaus. Physical examination of employees in the mines does not obtain. In Ohio, especially, there is a general shortage of physicians and in both states nurses are practically unknown in mining towns. Nostrum and quackery propaganda flourish, although non-medical practitioners are scarce.

Health Hazards According to Occupation

The 43,637 employees (a) within the Ohio mines for the year 1917 were divided as follows:

Pick miners	5,763
Inside day hands	10,175
Loaders, drillers and shooters	23,900
Machine miners and helpers	3,799
Total	43,637

The (b) outside workers totaled 6,282.

The employees (a) within the Illinois shipping mines for the year 1917 were divided as follows:

Cagers	753	Shot-firers	546
Drivers	4,263	Timbermen	1,422
Laborers	5,660	Trackmen	2,178
Loaders	24,529	Trappers	1,251
Machine men	3,957	Unclassified	8,546
Miners	24,951		

The outside or surface workers (b) totaled 7,337.

Investigations showed the health hazards for various occupational designations to be as follows:

Cagers. — Cagers and those who push mine cars around at the "bottom" or the exit of the mine, breathe the air after it has made the complete circuit of the mine, i. e., provided the return air is by way of the hoisting shaft or the exit roadway, which is usually the case. The air movement is also brisk. Fine dust is a feature. Humidity is high. Getting wet with water drippings is almost unavoidable. The work is active, often hurried and with short forceful strains. Workers should be medically picked.

Drivers. — Drivers including motormen, trip-riders, and mule or pony men, are usually youths. The work is muddy, often also dusty, in strong drafts, and quite hazardous in regard to accidents.

Laborers. — These are scattered about over the mine and have the hazards of the places in which they happen to work.

Loaders. — These men work at the face. They load the coal, whether pick or machine mined, into the mine cars. They are subjected to air conditions of the distant interior (work rooms), and to immense amounts of dust. Their work is laborious, on the tonnage basis, and when slack periods exist they are apt to sit around in cool, damp places. The air is fresher for these workers, however, than for those located along the return air way and at the bottom of the hoisting shaft (i. e., the cagers).

Machine Men. — These men have the ventilation hazards of the work rooms and are the most subject of all workers to breathing fine dust (bug dust). Most of the work is laborious and in strained attitudes. They are usually big, powerful men. Many also work at night, the machines undercutting the coal to be mined the next day.

Pick Miners. — The work of the miner is much less difficult than before the days of the extensive use of powder. They have the ventilation hazards of the work room. The dust hazard is great. Their work is laborious, on the tonnage basis and rather monotonous, with considerable jar, much spurt work interspaced with spells of waiting for mine cars, when they are apt to sit around in cool atmospheres and damp places. The pick miner, present days, does very little work "on the solid," i. e., picking at the coal in the seam directly. He uses drills and powder for this and picks the blasted-down chunks to pieces so they may be loaded by hand into the mine cars. He may or may not be his own loader.

Shot-firers. — These men, who are found in Illinois mines, fire the shots or blasts which have been placed by the coal miners during the last part of each day. Shot-firers go from room to room after hours

and touch off the fuses. Their chief hazards are breathing the fumes after shooting (white damp) and smoke and dust. They arrange their work, however, so as to keep on the fresh air side of the ventilation.

Timbermen have the ventilation hazards of work room and entries, more or less dust, also more or less wet work in many mines.

Trappers. — These men operate track switches and doors. Much of their time is spent in waiting. They may be in strong drafts carrying various amounts of dust. They are usually youths.

Tipple Men. — These workers are on the surface at the entrance of the mine shaft and have the hazards of weather exposure, but more especially, the breathing of a great deal of coal dust; occasionally, also, smoke and fumes from the burning dump piles where these exist. The *weighmen* are usually in enclosed quarters in the top of the tipple.

Track Men. — Those on the surface move railroad cars along and spread the coal within them. They have weather exposure, and the breathing of a great deal of coal dust. Those within the mine lay and repair tracks.

Hoisting Engineers. — These men may have exposure to excessive temperatures (100 to 140°F.) where steam hoists are used — a dangerous feature, since these men must be constantly on the alert, as with their levers they guide the raising and lowering of cages by means of signals from bells or whistles. The heat comes from non-insulated steam engines and pipes which surround the engineer's platform.

Child Labor is practically no feature in Ohio or Illinois mines. Youths under sixteen are prohibited by law from entering a mine. One hazard is that youths begin work in mines, without preliminary physical examination to determine whether they are fit for such work. Slate picking is no feature in soft coal mines. All coal is picked over at the face by the loader or miner to free it from sulphur, rock, etc.

Stripping Mines. — The chief health hazards are weather exposure, particularly heat in the summer time while working in low places. Also men in steam shovels are considerably exposed to heat from furnaces. There are some risks from blasting powder fumes and dynamite.

Coal Washing. — This accessory process is carried on at a few mines. It is done on the surface in more or less open buildings. Weather exposure with wet work and a great deal of dust from the crushing processes are the chief hazards. Noise is a marked feature.

The Special Health Hazards

"Dirt" piles or Gob. — As entries and rooms are extended, the refuse ("bone") coal, slate, rock, pyrites, soapstone, clod, timbers, etc., are heaped to either side. A certain amount of decomposition takes place in this, occasionally leading to spontaneous fires usually emitting carbon monoxide from incomplete combustion and sometimes hydrogen sulphide gas. The gob crumbles up much and adds to the dust in the air and the mud underfoot, also to the danger of accidents.

Dust. — Coal dust itself is regarded as among the least harmful dusts. It creates a catarrhal condition which tends to remove it from the respiratory tract. But much crystalline and gritty dusts are breathed by the miner as well as acrid sulphur compounds. The harmful dusts may be listed about as follows in ascending order of harmfulness to the miner: coal, timber, clay, soapstone, shale, slate, softer rock, sandstone, granite, and sulphur (pyrites). The last three or four dusts are very prevalent. When breathed they tend to remain fixed in the lungs and to bring about fibrosis, chronic bronchitis, emphysema, and lymphadenitis, the whole characterized as "miner's asthma."

Illumination. — Illumination is no longer a hazard for miners since much of the bottom is supplied with electric lights and miners use the modern carbide lamps, attached to the caps. Oil lamps are all but gone. Safety lamps, fortunately, with their imperfect illumination, are not required for work in Ohio or Illinois mines. Occasionally, men complain of the glare from brilliant carbide miner's lamps, the candle power of which ranges from 4 to 6, head-on.

Heat. — Miners are not exposed to high working temperatures. Steam hoisting engineers may have undue exposure, Temperature in Illinois' deepest mine may run up to 80°F. but invariably workers are subject to less than 70°F.

Cold. — The temperature of mines is invigorating. As long as workers keep active, the rather low temperatures of themselves should be considered no hazard.

Humidity. — Dripping roofs, mud, and dampness characterize most Ohio mines.

Dryness characterizes Illinois mines, but the atmosphere of all mines is usually nearly saturated with moisture derived from the strata by the time it leaves the mine. Hence, most of the workers are in a cool moist temperature (highly contaminated with dust). The water and humidity greatly increase electrical hazards.

Fatigue. — Faulty postures while under strain and work of jarring, vibrative character, heavy lifting and the employment of a certain percentage of men ill-fitted physically for the work, are the chief hazards. The muscular fatigue, however, is probably no hazard to normal men of proper build and experience. In some mines the competition to get empty mine cars to fill, leads to much " spurt " work.

Infection. — The disposal of stools in the gob, as is the prevailing method, can be made safe. The extent to which coal mine dust may transport virulent germs, as from spitting, has not been investigated; the hazard is probably insignificant. Diseases from animals, such an anthrax, glanders, and lockjaw, the latter in spite of the presence of horses or mules in all mines, do not appear to exist. In the presence of the black plague, the rats and mice in mines would be a great menace. Injuries which miners receive are at least as free from secondary infections, if not more so, than in most classes of workers.

Electricity. — In addition to burns and shocks, and occasionally electrocutions, the witnessing of brilliant electric flashes occasions some *electrica ophthalmia* — a painful swelling of the eyes which may persist up to fourteen days. Electric lights, motors, trolleys, rails, signals and telephones are found in mines and necessarily in close proximity to workers.

Poisons. — These concern mine gases almost solely. The chief mine gases are of three types: *fire damp* (methane, " gas," CH_4) which is explosive but not dangerous to health except as it replaces oxygen and then causes suffocation; *black damp* (choke damp, where carbon dioxide and nitrogen are increased at the expense of oxygen); and *white damp* (carbon monoxide). *Stink damp* (hydrogen sulphide, H_2S) is rarely found in mines. Sulphur occurs as pyrites and in acid forms, the latter dissolved in water and often strong enough to eat holes in clothing or to cause ulcers in the eyes if gaining access to them. In dust form it irritates the throat, nose and lungs.

Assuaging of Thirst. — Questionable water supplies in many instances make miners liable to typhoid fever, dysentery, and water-borne diseases. Alcoholic beverages are not permitted while at work.

Personal Hygiene. — Miners are in great need of instruction in matters of personal hygiene and the prevention of sickness. A large per cent. of miners' illnesses could be curtailed by this means.

Mortality

The studies of mortality of soft coal miners have been based upon the figures for Illinois. Illinois leads all other states in having available (through the efforts of the United Mine Workers in the state) figures on the average number of employees at a given time in the soft coal industry, and a record of each coal miner's death for the past ten years. These records, which are even more accurate than the standard death certificate since they are checked by the Union, have resulted from the Deaths Claims Insurance maintained by the state organization by which a burial fund amounting to $250 is paid to the beneficiary on the occasion of the death of any miner. In order that former or unemployed miners may remain in good standing and thus insure the burial payment, an exoneration list is maintained to which 7 per cent. of the total number of miners belong (October, 1918). The exoneration list has extended from a former rate of about 5 per cent. of the total membership to 7 per cent. recently, because of the increased exonerations allowed for war service.

These records enabled the Illinois Health Insurance Commission and the writer to compile Tables 1, 2, 3, 4, and 5.

TABLE 1. — GENERAL MORTALITY AMONG ILLINOIS COAL MINERS

(February 1, 1912 to July 21, 1918. — Approximately $6\frac{1}{2}$ years.)

Fiscal Year	Number of Deaths	Average Yearly Membership	Death-Rate per Annum per 100,000 Employed
Feb. 1, 1912–1913	742	73,955	1,003
Feb. 1, 1913–1914	800	75,161	1,064
Feb. 1, 1914–1915	825	76,093	1,071
Feb. 1, 1915–1916	784	70,903	1,105
Feb. 1, 1916–1917	832	74,942	1,110
Feb. 1, 1917–Jan. 1, 1918	893	83,489	1,167
Jan. 1, 1918–July 1, 1918	555	93,651	1,185

The last column in Table 1 shows that the death rate for Illinois coal miners has been constantly on the increase since 1912.

The marked excess in deaths due to violence nullifies to a large extent any comparisons possible between the other causes

TABLE 2. — MORTALITY OF ILLINOIS COAL MINERS FROM SELECTED CAUSES OF DEATH
(February 1, 1912 to July 21, 1912. — Approximately 6½ years.)

Cause of Death	International List No(s).	For the Four Year Period, Feb. 1, 1912 to Jan. 31, 1916 [1]	For the 2½ Year Period, Feb. 1, 1916 to July 21, 1918 [2]	Total Numbers of Deaths	Percentage Distribution of Deaths	Death-Rate per Annum per 100,000 Employed [3]
Typhoid Fever	1	104	50	154	2.8%	30.8
Malaria	4, 4a	6	5	11	0.2	2.2
Tetanus	24	5	1	6	0.1	1.2
Tuberculosis	28 to 35	277	221	498	9.2	99.4
Cancer	39 to 46	109	98	207	3.8	41.4
Cerebro-Spinal Diseases	60 to 79	153	135	288	5.3	57.5
Circulatory Diseases	77 to 85	212	190	402	7.4	80.3
Pneumonia	91 and 92	252	239	491	9.1	98.1
Other Respiratory Diseases	(86 to 90) (93 to 98)	158	55	213	3.9	42.6
Liver Cirrhosis	113, 113a	47	41	88	1.6	17.6
Genito-Urinary (non-venereal)	119 to 127	124	129	253	4.7	50.5
Suicide	155 to 163	102	58	160	3.0	31.9
Violence [4]	164 to 186	1,205	790	1,995	36.8	398.2
All Others	all others	408	254	662	12.2	132.1
Totals		3,162	2,266	5,428	100.2	1,083.9

[1] From figures compiled by Duncan McDonald, former Sec.-Treas., U.M.W.A., District of Illinois.

[2] From death claim records at office of Walter Nesbitt, Sec.-Treas., U.M.W.A., compiled by the Illinois Commission on Health Insurance.

[3] The average monthly number of employees throughout the whole period of approximately six and one-half years was 77,051. The casual reader should not compare the rates in this column, which are for adult males only, with the rates of death from similar causes in the population at large.

[4] "*Violence*" includes all external causes other than suicide.

Some deductions based on Table 2 may be made by comparisons with percentage distribution of deaths in other groups, as with:

(a) The U. S. Registration Area for 5,663 miners and quarrymen as given in Mortality Statistics, U. S. Bureau of Census, 1909, Table VIII, pages 402, 403 (see Table 3 below); and

(b) The U. S. Registration Area for 210,507 occupied males, 10 years of age and over, as given in Mortality Statistics, U. S. Bureau of Census, 1909, Table VIII, pages 388, 389 (see also Table 3).

While it is true that comparisons as arranged in Table 3 are not quite logical, principally because periods of even date are not compared, nor have soft coal miners been separated out of the federal figures, they are the best that can be had at present.

Violence as a cause of death in Illinois coal miners ranks 2.3 points less than in miners and quarrymen in the registration area. This cause, however, for both Illinois coal miners and miners and quarrymen is greatly in excess of the violence percentage in occupied males in the registration area (10.6 per cent of all deaths*).

* But one other occupation, steam railway employees, with 53.6 per cent. of all deaths due to violence, surpasses miners and quarrymen; the next occupation to approach it is lumbermen and raftsmen — 29.9 per cent. Consult U. S. Mortality Statistics, 1909, Table VIII.

of death and the figures given under occupied males in the last column. It does not affect, however, comparisons between Illinois coal miners and miners and quarrymen.

By eliminating the distortion due to violence as a cause of death, and then com-

TABLE 3. — SOME COMPARISONS OF THE PERCENTAGE DISTRIBUTION RATES OF CERTAIN CAUSES OF DEATH FOR ILLINOS COAL MINERS AND OTHER GROUPS

Causes of Deaths [1]	5,428 Deaths Among Illinois Coal Miners, 1912–1918	5,663 Deaths Among Miners and Quarrymen, U. S. Reg. Area, 1909	210,507 Deaths Among Occupied Males, U. S. Reg. Area, 1909
Typhoid Fever	2.8%	2.3%	2.2%
Tuberculosis	9.2	8.8 [3]	14.8 [3]
Cancer	3.8	3.3	5.5
Cerebro-Spinal	5.3	4.9	9.8
Circulatory Diseases	7.4	8.8	16.1
Pneumonia	9.1	8.2	8.0
Other Respiratory Diseases	3.9	4.3	10.2
Liver Cirrhosis	1.6	1.0	1.8
Genito-Urinary (non-venereal)	4.7	4.0 [4]	8.5 [4]
Suicide	3.0	1.5	2.6
Violence [2]	36.8	39.1	10.6

[1] See Table 2 for corresponding International List Numbers.

[2] See Note 4, Table 2.

[3] *Tuberculosis of lungs* only.

[4] *Bright's disease* only.

paring the purely medical causes (with suicide included) a clearer insight is obtained of the relative importance of certain prominent death causes.

As compared to miners and quarrymen in general, Illinois coal miners *rank;* (a) *about the same* with respect to tuberculosis and cerebro-spinal diseases; (b) *more favorably* with respect to circulatory diseases and "other" respiratory diseases; and (c) *less favorably* with respect to typhoid fever, cancer, pneumonia, liver cirrhosis, genito-urinary (non-venereal) diseases, and suicide.

TABLE 4.—SOME COMPARISONS OF THE PERCENTAGE DISTRIBUTION RATES OF CERTAIN CAUSES OF DEATH FOR ILLINOIS COAL MINERS AND OTHER GROUPS, WITH VIOLENCE EXCLUDED

Causes of Deaths [1]	5,428 Deaths Among Illinois Coal Miners, 1912–1918	5,663 Deaths Among Miners and Quarrymen, U. S. Reg. Area, 1909	210,507 Deaths Among Occupied Males, U. S. Reg. Area, 1909
Typhoid Fever.....	4.4%	3.8%	2.5%
Tuberculosis.....	14.6 [2]	14.4 [3]	16.6 [3]
Cancer.....	6.0	5.4	6.2
Cerebro-Spinal.....	8.4	8.0	11.0
Circulatory Diseases.	11.7	14.5	18.0
Pneumonia.....	14.4	13.5	8.9
Other Respiratory Diseases.....	6.2	7.1	11.4
Liver Cirrhosis.....	2.5	1.6	2.0
Genito-Urinary (non-venereal)....	7.4	6.6 [4]	9.5 [4]
Suicide.....	4.7	2.5	2.9

[1] See Table 2 for corresponding International List Numbers.
[2] Total tuberculosis; however, probably not more than 1 per cent. is due to other forms of tuberculosis than tuberculosis of the lungs in persons of these adult age-groups.
[3] *Tuberculosis of lungs* only.
[4] *Bright's disease* only.

As compared with occupied males in general, Illinois coal miners *rank* (a) *about the same* with respect to cancer and liver cirrhosis; (b) *more favorably* with respect to tuberculosis (although the difference is not great), cerebro-spinal diseases, circulatory diseases, other respiratory diseases, and genito-urinary (non-venereal) diseases; and (c) *much less favorably* with respect to typhoid fever, pneumonia * and suicide.

Unfortunately, similar, more recent figures from the U. S. Bureau of Census have not been compiled. Mortality statistics for soft coal miners or groups with similar hazards in other states have also not been prepared elsewhere to the writer's knowledge.

* Pneumonia is said to be a common aftermath of carbon monoxide poisoning. (Glaister and Logan, *Gas Poisoning in Mining and Other Industries*, 1916, p. 109.)

Table 5 allows some conclusions to be drawn from the death rates ascertained in Illinois coal miners by causes and age-groups.

Table 5 shows two things: (1) the age-groups in which certain causes of death are emphasized in Illinois coal miners, and (2) the tendencies toward increase or decrease in the various causes of death, obtained by comparing the death rates in the last column, which are those of the last two years (1916–18), with those for the entire period (1912–18, see Table 2). From these we have the following:

1. *Tuberculosis* shows its main emphasis in the age-group, 25 to 34, with a gradual decline thereafter throughout the balance of the age-periods.

Pneumonia shows a gradual increase with age, up to the age-period, 45–54, then a gradual decline.

The figures for *other respiratory diseases* are too small for deductions, but in general show most emphasis later in life.

Cancer and *cerebro-spinal diseases* both show a marked increase in the age-period, 35 to 44, then a more gradual increase to the age, 64, after which there is a drop.

Circulatory diseases are emphasized from 45 years of age up.

For *liver cirrhosis* the figures are too limited for discussion.

The *non-venereal genito-urinary* diseases, *Bright's disease* principally, show a gradual increase by age-periods up to and including the age-period, 55–64.

The figures for *suicide* and *violence* were not compiled for age-periods.

"*All other diseases*" have a very even distribution throughout the age-periods, there being emphasis on the period, 25–34, and less emphasis on the period, 55–64.

2. Comparing the last column in Table 5 with the last column in Table 2, it is seen that for Illinois coal miners the death rate per 100,000 employed is apparently on the increase in the case of the following diseases: tuberculosis, cancer, cerebro-spinal diseases, circulatory diseases, pneumonia, liver cirrhosis, genito-urinary (non-venereal) diseases, and violence.

Deaths from the following show a decreasing tendency: "other respiratory diseases" and suicide.

It is hardly more than speculation to attempt to state to what the apparent increase in mortality among Illinois coal miners is due. Violence as a cause of death has not increased materially. Working conditions are undoubtedly getting better from year to year. Unquestionably, it cannot be charged to any single factor, such as alcoholism, which has been on the decrease throughout the period covered in the tables; nor fatigue, since work hours have

decreased while the assistance of blasting powder and machinery have increased; nor, with the exception of certain diseases like typhoid and malaria, has geographical distribution in the state anything to do with it.

It is probable that more are reaching the later age-periods when deaths are more frequent, since the industry is not, in its present dimensions, more than a generation old in Illinois and barely more so in Ohio.

TABLE 5. — MORTALITY OF 1889 ILLINOIS COAL MINERS GROUPED BY CAUSES AND AGE-GROUPS

(Figures cover the two year period from July 22, 1916 to July 21, 1918.)

Age-Groups	15–24		25–34		35–44		45–54		55–64		65–Over		Age Not Given		Total		Rate per Annum per 100,000 Employed [3]
Causes of Death [1]	No.	% [4]	No.	% [4]	No.	% [4]	No.	% [4]	No.	% [4]	No.	% [4]	No.	% [4]	No.	% [5]	
Tuberculosis	26	14.6	47	26.4	35	19.6	33	18.6	24	13.4	13	7.3	0	..	178	9.4	106.5
Cancer	0	0	7	9.2	15	19.7	20	26.3	22	28.9	12	15.7	0	..	76	4.0	45.4
Cerebro-Spinal Diseases	9	7.6	9	7.6	24	20.5	25	21.3	27	23.0	22	18.8	1	0.9	117	6.1	70.0
Circulatory Diseases	6	3.9	17	11.2	18	11.9	36	23.8	38	25.1	36	23.8	0	..	151	7.9	90.3
Pneumonia	10	5.0	36	18.1	39	19.6	49	24.7	38	19.1	26	13.1	0	..	198	10.4	118.5
Other Respiratory Diseases	1	2.2	6	3.3	4	8.8	11	24.4	7	15.5	16	35.5	0	..	45	2.3	26.9
Liver Cirrhosis	3	8.1	2	5.4	9	24.3	8	21.6	12	32.4	3	8.1	0	..	37	1.9	22.1
Genito-Urinary (non-venereal)	2	1.9	9	8.8	11	10.7	19	18.6	38	37.2	22	1.5	1	1.0	102	5.3	61.1
Suicide	..	..	..	..	..	..	..	..	..	..	..	..	..	..	49	2.5	29.3
Violence [2]	..	..	..	..	..	..	..	..	..	..	..	..	..	..	676	35.7	404.6
All Other Diseases	41	15.7	55	21.1	44	16.7	141	15.7	32	12.3	42	16.1	5	1.9	260	13.7	155.6
Total	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,889	99.2	1,130.2

[1] See Table 2 for corresponding International List Numbers.
[2] See Note 4, Table 2.
[3] The average monthly employment was 83,537 men. The casual reader should not compare the rates in this column, which are for adult males only, with the rates of death from similar causes in the population at large.
[4] Per cent. here means the distribution of deaths by age-groups per 100 deaths from the given cause.
[5] Per cent. here means the distribution of deaths by causes per 100 deaths from all causes.

It is probable also that a change in racial complexion to a greater percentage of foreigners is a factor. It is more than likely that a greater congestion of population and its attendant evils, without a corresponding increase in health supervision of housing and living conditions, are potent and basic factors.

The 1889 deaths occuring in the two-year period, July 22, 1916 to July 21, 1918 (see Table 5), were classified also by the twelve districts composing the coal field of the state. Without exhibiting a table, the following was deduced: With the exception of the few deaths recorded from malaria and typhoid fever, which have locality emphasis, all the remaining causes of death were fairly evenly distributed in proportion to the number of miners in each district.

The death rate of Illinois coal miners from specific causes (Table 2) when compared with the same for the entire U. S. Registration Area (Mortality Statistics, 1916, p. 19) *is directly excessive* for the following diseases: typhoid fever, 30.8 *vs.* 13.3; cirrhosis of liver, 17.6 *vs.* 12.3; suicide, 31.9 *vs.* 14.2; and violence, 398.2 *vs.* 90.9.

Summary of Mortality Statistics

1. The annual death rate of Illinois coal miners is steadily increasing.

2. Death rate comparisons with exactly similar groups elsewhere cannot be made because similar statistics elsewhere have not been compiled. The percentage distribution of deaths from different causes shows that rates for Illinois miners are about the same as for miners and quarrymen in the registration area, 1909, and that for this class of employees, external causes (violence) make up nearly two-fifths of all deaths, whereas violence for all occupied males makes up but one-tenth of all deaths.

3. By eliminating the distortion due to violence as a cause of death, it is found that the percentage ratios for specific medical causes of death show (a) insignificant differences as between Illinois coal miners and quarrymen in the registration area, but (b) rather remarkable differences as between Illinois coal miners and all occupied males. In particular, Illinois coal miners have a tuberculosis percentage not much under that of all occupied males, while their figures for circulatory diseases are much lower, but those for typhoid fever, pneumonia and suicide are much higher.

4. Tuberculosis, as elsewhere, shows its main emphasis in the age-group, 25 to 34 years. Pneumonia shows its emphasis in the age-group, 45 to 54 years.

5. All the specific causes of death discussed (Tables 2 and 5) show a tendency to increase as years go by with the exception of "other respiratory diseases" and suicide. The causes for these tendencies are undoubtedly many and complex.

6. With the exception of typhoid fever and malaria none of the specific causes of death are emphasized in any particular locality of the coal field.

7. When compared with the rates for the entire population in the registration area, the death rates for Illinois coal miners are directly excessive from typhoid fever, liver cirrhosis, suicide and especially violence.

Suggestions for Improved Health Conditions in Mining Centers

1. Insist on extending the principles of rural sanitation to mining towns.

2. There should be a community health service organization.

3. More aid should be extended to the respective state mining departments, particularly in the nature of hygienists' services. There should be closer co-operation with state health departments.

4. There should be a standardization of the many existing forms of health or sickness insurance which now prevail.

5. The author advocates state health insurance and the doing away with optional memberships.

6. More hospital, dispensary, nursing, diagnostic, and social services.

7. Physical examinations, particularly at the time of employment and preferably by state or federal employment agencies.

8. Limitation of nostrum and quackery propaganda.

9. Propaganda in health standards and ideals.

10. Promotion of Americanization, particularly in districts of foreigners.

11. All persons or service shaving to do with sanitation or medical care should be licensed, and preferably annually, as a check against unscientific methods.

BOOK REVIEWS

The Shop Committee, a Handbook for Employer and Employee. By William Leavitt Stoddard, Administrator for the National War Labor Board, 1918–1919. Pp. 100, with appendix. New York: The Macmillan Company, 1919.

As the writer points out in the foreword, this book is the result of his experiences with the War Labor Board and as an independent student of the problems of the shop committee. Aside from the fund of valuable information and conclusions which Mr. Stoddard has so ably presented, the book possesses an atmosphere of enthusiastic familiarity with the subject of shop committees, which makes its reading unusually pleasant.

After discussing briefly the history of the shop committee movement as exemplified in the Colorado plan, the British experiences growing out of the Whitley report, and the work of the War Labor Board in this field, Mr. Stoddard takes up in some detail the plans followed by the War Labor Board in directing the organization of shop committees. After following the development of the Pittsfield plan, the principles of general procedure arrived at by the War Labor Board are given.

Among the important characteristics of the shop committee given under the treatment of "General Principles" should be noted the following: "In the shop committee system government, there are two sources of power." "The relations between employer and employee . . . are controlled jointly or collectively *up to a certain point only*." "Within certain limits of common sense every employee should have the right to vote." No shop committee system can succeed where the management considers itself morally or intellectually the superior of the men.

From the discussion of general principles, the writer proceeds to details closely connected with them. Among these are the questions of representation, election machinery, and methods of procedure. The latter part of the book also deals with plans illustrative of variations of the War Labor Board's policy in organizing shop committees.

If the text of this excellent little book could be summed up in a single word, the word would be *cooperation*. The necessity for a feeling of mutual sympathy and a willingness to compromise is constantly held before the reader.

Mr. Stoddard is extremely hopeful for the future of the shop committee. He sees no fundamental antagonism between the shop committee and labor unions. On the contrary, he feels that the shop committee is the first effective agency which has come into existence with a purpose sufficiently broad to reconcile organized labor on the one hand and organized capital on the other. — *C. H. Paull.*

The Blind: Their Condition and the Work Being Done for Them, in the United States. By Harry Best, Ph.D. Cloth. Pp. 740, and index. New York: The Macmillan Company, 1919.

This is a very thorough treatise of the status and treatment of the blind in the United States, containing full statistics covering every possible phase of the subject, with recommendations based upon observations made and with very full bibliographical notes accompanying the treatment of each subject.

The work is divided into seven parts. *Part I* takes up the general condition of the blind: how many there are in the United States; their position in society; their legal status; their economic condition; and the cost of blindness to the individual and to the state. *Part II* takes up the possibilities of prevention of blindness — the object of foremost concern to the author. This involves a careful examination of the causes of blindness, and the proportion of cases preventable by present known means; of the extent and manner of preventing accidents and injuries to the eye; and of the organized movements set on foot to prevent blindness. *Part III* takes up the provision made for the education of blind children. *Part IV* takes up the intellectual provision for the adult blind. *Part V* is concerned with the material provision made for the blind: (1) the special homes for the blind; (2) the special industrial establishments; (3) all other forms of industrial provision for the blind in the general normal industrial ranks of the community; (4) pensions for the blind, the extent to which this system has already been developed, and its advisability; (5) the system of indemnification, applicable in three forms, i. e., through suits at law, personal insurance, and workmen's compensation laws. *Part VI* is a description of the various organizations which have been established to promote the general welfare of the blind, including private associations and public commissions. The special provisions made by the national government for persons blinded in military service are also reviewed. *Part VII* sets forth conclusions reviewing the work for the blind as a whole in the United States, and the manner in which existing methods of relief may be improved.

For the industrial manager interested in the prevention of blindness and in the material provision for those who have become blind, *Part II* and *Part V* will prove of particular interest. — *L. A. Shaw.*

BOOKS RECEIVED

Books received are acknowledged in this column, and such acknowledgement must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

Helping France. A Story of the Red Cross in the Devastated Area. By Ruth Gaines. Cloth. Pp. 235, with illustrations. New York: E. P. Dutton & Company, 1919.

New Towns After the War. An Argument for Garden Cities. By New Townsmen. Paper. Pp. 84. London: J. M. Dent & Sons, Ltd., 1918. New York: E. P. Dutton & Company.

Government Control of the Liquor Business in Great Britain and the United States. By Thomas Nixon Carver, Professor of Political Economy, Harvard University. Carnegie Endowment for International Peace. Preliminary Economic Studies of the War, No. 13. Edited by David Kinley, Professor of Political Economy, University of Illinois; Member of Committee of Research of the Endowment. Paper. Pp. 192. New York: Oxford University Press, 1919.

LECTURES BY DR. T. M. LEGGE*

Harvard University announces the following lectures by Dr. T. M. Legge, Chief Medical Inspector of Factories and Workshops in Great Britain.

Lowell Lectures of the Lowell Institute

To be given in Huntington Hall, 491 Boylston Street, Boston, Mass., at 8 P.M., as follows:

1. Monday, Nov. 17. Industrial Diseases under the Medieval Trade Guilds.
2. Thursday, Nov. 20. The Spirit of Work under the Medieval Trade Guilds.
3. Monday, Nov. 24. Modern Industry and Art.
4. Wednesday, Nov. 26. The Edward Medal and Gassing Accidents.
5. Monday, Dec. 1. Industrial Poisons and their Prevention.
6. Thursday, Dec. 4. Anthrax.

The Cutter Lectures on Preventive Medicine and Hygiene

To be given at the Harvard Medical School, Amphitheatre Building E, 240 Longwood Avenue, Boston, Mass., at 5 P.M., as follows:

1. Tuesday, Nov. 18. Twenty Years' Experience of the Notification of Industrial Diseases under the Workmen's Compensation Act.
2. Wednesday, Nov. 19. Industrial Diseases under the Workmen's Compensation Act.
3. Friday, Nov. 21. Medical Supervision in Factories.

* Owing to unexpected demands on Dr. Legge's time, at the eleventh hour his lectures have had to be postponed to somewhat later dates. The JOURNAL OF INDUSTRIAL HIGYENE will be glad to send to anyone requesting such information, the dates of the lectures when finally scheduled. — *Ed.*

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912

Of JOURNAL OF INDUSTRIAL HYGIENE, published Monthly at Boston, Mass., for October 1, 1919.

State of New York..... } ss.
County of New York..... }

Before me, a notary public in and for the State and county aforesaid, personally appeared J. Norris Myers, who, having been duly sworn according to law, deposes and says that he is the Business Manager of the JOURNAL OF INDUSTRIAL HYGIENE, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 443, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, The Macmillan Company, 64–66 Fifth Ave., New York City. Editor, Dr. David L. Edsall, 240 Longwood Ave., Boston, Mass. Managing Editors, Drs. C. K. and K. R. Drinker, 240 Longwood Ave., Boston, Mass. Business Manager, J. Norris Myers, 64–66 Fifth Ave., New York City.

2. That the owners are: The Macmillan Company (Inc.), 64–66 Fifth Ave., New York City. Stockholders owning more than 1 per cent of stock are: Maurice Macmillan, 52 Cadogan Place, London, S. W., England. Sir Fred'k Macmillan, 22 Devonshire Place, London, W., England.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent. or more of total amount of bonds, mortgages, or other securities are: None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company, but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustee, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the six months preceding the date shown above is Monthly. (This information is required from daily publications only.)

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Sworn to and subscribed before me this 18 day of September, 1919.

H. W. MYERS
(My commission expires March, 1920.)